AN INVESTIGATION OF THE DEFENSE LOGISTICS AGENCY'S DEDICATED TRUCK PROGRAM

THESIS

Theresa O. Cantrell, Captain, USA
Walter E. Van Daele, Major, USA

AFIT/GIR/LAL/93D-2

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
Wright-Patterson Air Force Base, Ohio

AFIT/GIR/LAL/93D-2

AN INVESTIGATION OF THE DEFENSE LOGISTICS AGENCY'S DEDICATED TRUCK PROGRAM

THESIS

Theresa O. Cantrell, Captain, USA
Walter E. Van Daele, Major, USA

AFIT/GIR/LAL/93D-2

The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

AFIT/GIR/LAL/93D-2

AN INVESTIGATION OF THE DEFENSE LOGISTICS AGENCY'S DEDICATED TRUCK PROGRAM

THESIS

Presented to the Faculty of the School of Logistics and
Acquisition Management of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Information Resource Management

Theresa O. Cantrell, B.S.
Captain, USA

Walter Van Daele, B.A.
Major, USA

December 1993

Acknowledgments

Through good and bad, through war and peace our spouses took it all in stride. Now they have faced the ultimate challenge and stayed with us through the thesis process. Their support and understanding have allowed us to achieve this goal, while their love and patience have maintained our sanity. Danke Gleichfalls!

To David and Heather, to Sean and David we offer our thanks. For tolerating our absences, lack of attention, and bad moods you have given your share to ensure our success.

In collecting data and information we had help from many sources. Personnel at all three Defense Distribution Regional offices, at DPSC, DLA, and LCA contributed their time and effort to assist us in our research. We offer special thanks to Barry Miller at DPSC and Bill Spinelli at LCA. Thanks to everyone for their assistance.

Throughout the thesis process we enjoyed the support and guidance of our advisors, LtCol Deiner and LtCol Templin. For clarification of confusing statistical quandaries, we would like to thank Dr. Dan Reynolds.

The fat lady is singing!

Theresa O. Cantrell

Walter Van Daele

Table of Contents

List of Figures

List of Tables

Abstract

In 1990, the Department of Defense purchased medical materiel from the Defense Logistics Agency totaling approximately $1 billion dollars. Congress has directed the Department of Defense to examine civilian healthcare practices to reduce these costs.

Just-in-Time inventory management is one of those practices. Research on Just-in-Time inventory for military facilities raised several concerns about its capability to support the military mission. However, there are many facets of Just-in-Time management that can be adopted without compromise of wartime capabilities.

This research identifies the results of the change in the Defense Logistics Agency's policy on delivery of medical materiel to Department of Defense medical facilities. The change was intended to decrease delivery time and increase reliability. It was hoped that in turn these changes would create savings and reduce inventory levels.

Statistical analysis of six pairs of hospitals, test and control, did not show any conclusive change in the delivery time although some individual hospitals did experience a decrease.

The increase in reliability was significant. Although a few hospitals experienced a slight increase, most hospitals experienced a decrease in variance resulting in increased reliability and customer satisfaction.

AN INVESTIGATION OF THE DEFENSE LOGISTICS AGENCY'S DEDICATED TRUCK PROGRAM

I. Introduction

Overview

A recent Government Accounting Office (GAO) report outlines the reasons for the Department of Defense (DOD) and Defense Logistics Agency (DLA) interest in medical supply inventory management.

> In fiscal year 1990, these 125 medical facilities purchased approximately $1 billion in consumable medical supplies such as drug items, needles, and sponges. To support this hospital network, DOD maintains 443 warehouses and a depot system of 17 warehouses that hold inventory valued at more than $824 million. (GAO/NSLAD-92-58,1991:2)

The GAO report recommended the Department of Defense reduce the size of its standing inventory and related holding costs by adopting civilian practices such as Just-In-Time (JIT) inventory management. This technique centers around using suppliers who have the ability to provide supplies rapidly

with a high degree of reliability and thus allow hospitals to reduce overall inventory levels.

The Defense Logistics Agency and its subordinate operating agency, the Defense Personnel Services Center (DPSC), are the largest single suppliers of medical supplies to DOD hospitals. In December 1991, DLA/DPSC initiated the dedicated truck program designed to improve the speed and reliability of supply service to Just-In-Time standards.

Under the dedicated truck program, hospitals are grouped into geographical clusters. A schedule of regular shipments is set up, with frequency of delivery determined by average volume of supplies within the cluster. Trucks are contracted with direct delivery to each hospital within the cluster.

This thesis evaluates the success of the dedicated truck program. Specifically, the change in speed and reliability of delivery is measured by isolating and studying the components of order-ship time directly related to processing and shipment.

Background

Logistics operations, like so many specialties, have developed a language and system that must be understood. In

order to facilitate understanding of this introduction some of those terms are defined here.

Key Terms. The following terms are defined using citations from Army regulations. No substantial difference exists within DOD or the civilian sector in these definitions though the terminology itself may differ slightly.

Operating level (OL) is the quantity of stock needed to sustain operations in the interval between receipt of a replenishment shipment and submission of another replenishment requisition (AR 710-2-2, 1992:25). The current Army policy states, "operating level will be based on a 90 day requirement." (AR 40-61,1989:15).

The Order-Ship Time Level (OSTL) is the quantity of stock needed to sustain operations between the time a replenishment requisition is submitted and the resulting materiel receipt is posted to the account. This time is computed as a moving average by, "Using the six most recent receipts for an item, compute the average OST. In computing OST, exclude high priority requisitions and requisitions with long delays from wholesale backorder, unusual circumstances, or lack of funds" (AR 710-2-2, 1992:25). Order-Ship time is also referred to as lead-time or pipeline time in civilian journals.

Safety level (SL) is the quantity of stock on hand to sustain operations in the event the demand rate changes or the OST becomes longer than expected. It is a safety factor

intended for use in emergencies or when replenishment receipts are delayed. (AR 710-2-2, 1992:25). Military hospitals compute inventory levels to include a 30-day safety level (AR 40-61, 1989:15).

Requisitioning Objective (RO) is the maximum quantity of an item that may be on-hand or on order at any one time. It consists of the operating, safety, and order-ship time levels (OL + OSTL + SL = Total Inventory = Requisitioning Objective) (DA PAM 710-2-2,1992:25).

Reorder Point (ROP) is the net asset quantity at which new stock is ordered. The ROP should equal the total quantity of OST and safety levels. Net assets are computed by adding quantity on-hand to quantity on order (Due In or DI) and subtracting any quantities owed to customers (Due Out or DO) (DA PAM 710-2-2,1992:25).

Materiel Release Order (MRO) is the written form (DA Form 2765-1, DD Forms 1348-1 or -6) that tells the warehouseman what, how many, and for whom to pull supplies (AR 725-50, 1988:6-2). The date this form is printed, also the date DPSC transmits the data (the order) to the depot, is the beginning date of depot processing time.

Uniform Materiel Movement and Issue Priority System (UMMIPS) provides the means for expressing the importance of a supply request. This is done by assigning a 2-digit numeric code, from 01 to 15, to the supply request when it is initiated (DODD Directive 4410.6). UMMIPS also sets the

standards for the number of days a unit can expect to wait to receive an item based on assigned priority.

Lead-time Determination. Department of Defense hospitals send their supply requisitions to DPSC through the Automated Defense Information Network (AUTODIN). DPSC, as the national inventory control point for medical supplies, determines if sufficient supplies are in stock to fill the order. If current stock on hand is insufficient, a backorder is established until additional stock is received and the order can be filled. If sufficient stock is available then the optimal depot location is determined for delivery to the requesting hospital. DLA operates three primary depots: Mechanicsburg, PA; Memphis, TN; and Tracy, CA. The Materiel Release Order (MRO) is then transmitted to the chosen depot via AUTODIN.

The depot is responsible for printing the MRO, pulling and packaging the supplies, contracting for transportation, and making the actual shipment. Trucks are hired by contract with commercial carriers. If the shipment is less than a full truckload, the truck often carries other freight and can take from two days to two weeks to deliver the hospital's supplies (Connelly, 1992). This leads to large variances in lead-time, also called order-ship time (OST).

Extremely long lead-times and/or large variations in lead-time cause high levels of safety stock to be maintained (Gerchak, 1991:191). The OST will also rise due to the

constant recalculation of this level (exact calculation formulas vary slightly based on the automation system used). The end result of this variation is an increased hospital inventory and its accompanying costs.

Order-ship time or lead-time can be measured with a variety of methods. The beginning date may be determined using the creation date of the order or the date of confirmed transmission receipt at DLA. The end date can be measured using a delivery receipt, transportation documents or receipt processing by the hospital. Most hospitals measure lead-time from the creation of the order to the receipt processing date. For the purposes of this research, the date the order is received at DLA is recorded as the beginning date while the ending date is based on the date the hospital processes the receipt from depot. This is due to variation in transmission methods between different hospitals and services causing variations outside DLA's control.

General Issue

DLA leadership is focusing its energies on specific issues integral to improving performance. (McHugh, 1991:7). Five strategic target areas are: (1) attracting and retaining quality people, (2) matching customer requirements with DLA capabilities to ensure customer satisfaction,

(3) deploying information systems that meet user needs, (4) lowering costs and maximizing return on investment, and (5) building an effective relationship with industry (McHugh, 1990:7).

This research focuses upon the Dedicated Truck program, which was implemented to meet the second goal, matching customer requirements with DIA capabilities to ensure customer satisfaction and the fourth goal, lowering costs and maximizing return on investment.

Specific Problem

The purpose of this research is to determine if the dedicated truck program reduces order-ship time and increases reliability resulting in improved customer service.

Investigative Questions

Several questions must be answered to determine if this program leads to improved customer service:

1. If a reduction in lead-time and lead-time variance has occurred, what effects should this have upon inventory levels?

2. How do lead-time and reliability affect customer service?

3. What components of lead-time are expected to be affected by the dedicated truck program?

4. Did a measurable decrease in lead-time occur in these components under the new program?

5. Did a measurable decrease in lead-time variance occur under the new program?

6. If a decrease in the lead-time or lead-time variance has occurred, can these be attributed to the implementation of the dedicated truck program, or can they be explained by other means?

Scope and Limitations

This research focuses on the components of lead-time that are under the control of DPSC and the effect of improvements in these components on inventory levels. Only military hospitals are included in the research although other federal facilities are also supplied by DLA. Only DPSC stocked items requested on a routine priority are included in this research. High priority requisitions, local purchase, non-standard items and other specially handled materiel are shipped by a variety of methods and are therefore outside the scope of this research.

Structure

Chapter II provides a basis for the measurement of lead-time, and exploration of its relationship and effect upon both inventory level management and customer service. The relationship to civilian business practices and Just-In-Time inventory practices is also established. The individual components of lead-time are defined with special attention to the components being measured in this research. This provides answers for investigative questions five and six.

Chapter III presents the methodology used to collect and analyze the data relating to the components of lead-time. It discusses the statistical methods used to examine the data and determine the significance of any reductions in mean or variance.

Chapter IV describes the findings and analysis of the statistical and modelling results, while Chapter V discusses the conclusions and their significance. In additional, areas for future research are suggested.

II. Literature Review

Overview

Lead-time directly affects the order ship time level component of inventory. Variance of lead-time has an equal effect on another of the components, safety level, and thus on overall inventory levels. Therefore the logistician is forced to maintain high levels of inventory when lead-time is long and highly variable in order to provide the quality of customer service demanded by health care professionals.

But what components of lead-time are affected by the dedicated truck program? And how does this program affect inventory levels?

This literature review describes the role and relationship of DLA and DPSC in the requisition flow of a routine request for medical supplies. It then, through a discussion of inventory management and JIT principles, establishes the relationship of lead-time and lead-time variance to customer service and reliability. Components of lead-time are defined and determination of which to use in this research is made. The review also provides a basis for linking lead-time and lead-time variance with safety stock and inventory levels.

Defense Logistics Agency / Defense Personnel Service Center

The Defense Logistics Agency's business is support, furnishing materiel support and services to all of the military services. DLA currently manages approximately 70 percent of all consumable items used by the services. To accomplish this mission DLA operates a network of supply centers, responsible for the management of day-to-day supply operations, and depots, which receive, store and issue the supplies managed by the supply centers (DLA, 1992:2).

The Defense Personnel Service Center is a DLA supply center responsible for management and day-to-day supply operations concerning food, clothing and textiles, medicines and medical equipment. DPSC, as a National Inventory Control Point, monitors inventory levels, awards contracts and processes requisitions for these commodities (DPSC, 1992:2).

DLA also operates supply depots assigned to three distribution regions. The depots receive, store and issue supplies managed by one or more of the supply centers (DLA, 1992:2).

Requisition Flow

Hospitals submit requisitions for medical materiel directly to the DPSC (AR 40-61, 1989:15) or through Base

Supply (AFM 67-1, 1991:8). These requisitions are transmitted by a variety of electronic means (DDN, Autodin, etc.) and routed through the Defense Automated Addressing System (DAAS).

After preliminary screening by the Standard Automated Materiel Management System (SAMMS), the requisitions for stocked items are checked against the on-hand quantity and the minimum stock level required by the Uniform Materiel Movement and Issue Priority System (UMMIPS). If the requisition cannot be filled, it is given a backorder status and held until it can be filled. If the requisition can be filled, it is matched for geographic location of the customer and preferred storage depot.

SAMMS generates a materiel release order (MRO) that is transmitted to the designated depot by AUTODIN at the end of the processing cycle. Cycles are completed twice daily Monday through Friday and once a day on Saturday and Sunday (McHugh, 1991:81). The flow of requisitions and supplies for medical materiel is depicted in Figure 1.

In 1990 a change in UMMIPS standards allowed the downgrading of all transportation priorities to routine processing with certain high-priority exceptions. This allowed the depot to place the MRO into a 'bank' for up to eight days in order to consolidate for common destinations (McHugh, 1991). Under the dedicated truck program, these requisitions are no longer banked. The MRO is processed, pulled, packed, and

shipped based on the scheduled shipment for the geographical cluster of the requesting hospital.

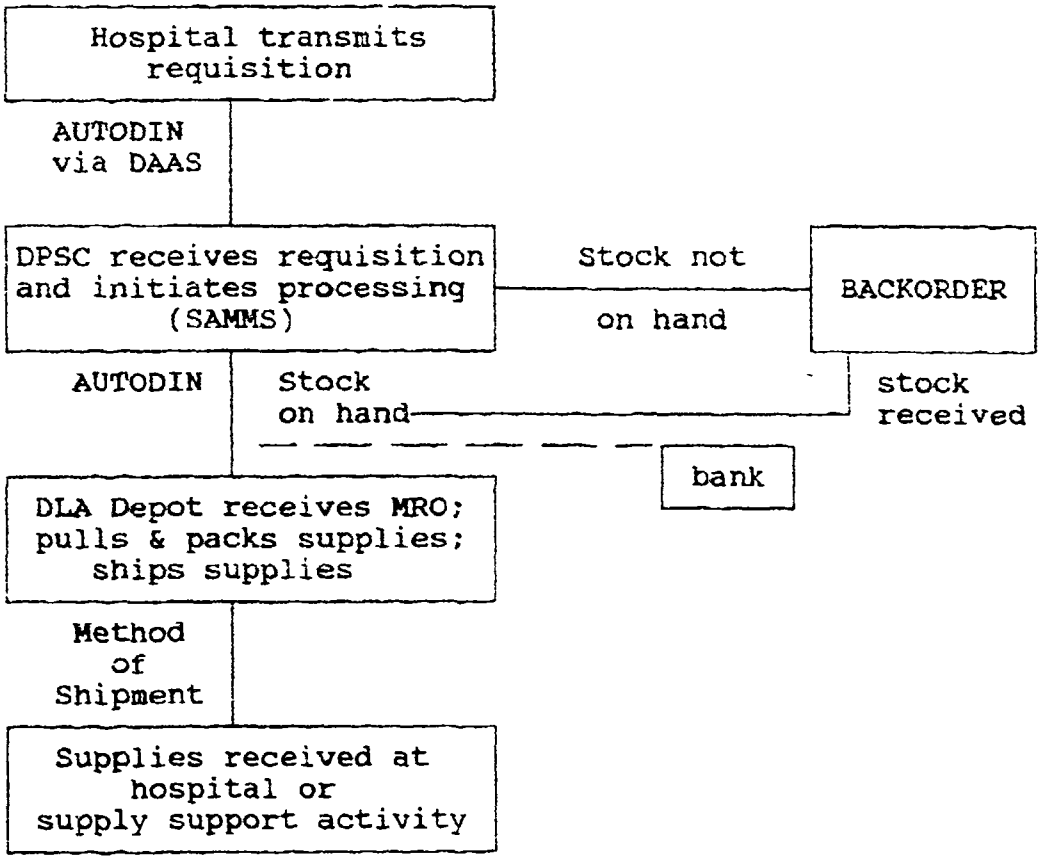

Figure 1. Flow of Medical Requisitions and Supplies

Throughout the requisition processing, the status of the requisition is sent to the requestor. At each step in the process, the status is updated and additional information such as release date, ship date or backorder is sent to the customer. This information is also picked up by the Army Logistics Control Agency (LCA) which acts as an

information clearinghouse for all Army materiel requisition status including medical materiel (Tesh, 1992).

Inventory Management

The purpose of inventory management is to have the right item at the right place at the right time in the right quality for the right price and the right person. This definition can be translated into four targets: (1) to have the required materiel on hand when needed; (2) to pay the lowest price for adequate quality; (3) to minimize inventory investment; (4) to operate efficiently (Ammer,1983:203).

Many of the current inventory methods have been described as Just-in-Case management, in other words, the stock must be on-hand in case it is needed. These methods lead to large inventories, high costs for maintaining the supplies, and waste if the supplies become spoiled or obsolete (Schonberger, 1982:14). Several of the management methods currently employed in the military are described in the following paragraphs.

Order-Point Controlled Replenishment (sometimes referred to as an "s,S" method of replenishment) selects a specific level to which the stock on hand must be depleted before a new order can be submitted. These orders may be made in accordance with a pre-determined order period; how

ever the order should incorporate the quantity necessary to gain the bulk purchase cost savings (Ammer, 1968:119).

Determining the order-point, also called the reorder point, is accomplished by using a Days of Supply (DOS) or Economic Order Quantity (EOQ) formula. Days of Supply (DOS) is based on the average quantity of an item required for a single day. In order to calculate this quantity, a control period of 360 days is used as the denominator. The total quantity ordered for a specific item during this period is the numerator (Example: 10 orders for 100 bandaids each = 1000 total quantity). Dividing the total quantity by the control period gives the average daily demand or one DOS (Example: 1000 bandaids per year/ 360 days = 2.78 bandaids per day = 1 DOS). Multiplying this quantity by the number of days required on-hand determines the operating level. The OSTL and safety level are determined by the same method (DA PAM 710-2-2,1992:25).

Economic Order Quantity (EOQ) is based upon the costs of inventory rather than the days of operation. The two main costs are possession and acquisition. These two costs consist of other associated costs. The cost of possession includes storage (warehouse space, salaries); obsolescence (expired, spoiled, lost, replaced); and capital (dollar value of the stock). The cost of acquisition consists of purchasing (cost per item) and ordering (transportation, processing, expediting, special handling or packaging).

EOQ balances the costs of possession against the costs of acquisition in determining the reorder point (Ammer, 1968:240).

Both EOQ and DOS formulas are currently used within DOD. Deployable hospitals and other deployable units maintain supplies under DOS (DA PAM 710-2-1,1991). For them it is essential to know how many days they can be deployed without resupply. Military hospitals may employ a variety of methods, however experience indicates that various forms of an EOQ calculation are the most widespread.

Just-In-Time. In contrast to Order-Point Controlled Replenishment, the current innovation in civilian inventory management practice is Just-in-Time inventory management. This method originated in Japan as an inventory system called Kanban or signboard (Nataraajan, 1991:19) and it has been widely adopted in the U.S. manufacturing industry. More recently it is becoming widespread in civilian hospitals, health organizations and among healthcare material manufacturers and distributors.

JIT is used extensively in the manufacturing sector, and has evolved from an inventory system to a management philosophy. In its original form, JIT modified the primary objective of supply (right item, right quality, etc.) by adding that the item should be delivered by the supplier just as it is needed, no sooner. Schonberger, in his definition of JIT, states:

> Produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies, and purchased materials just in time to be transformed into fabricated goods. (Schonberger, 1982:16)

Since a hospital is not a manufacturing plant, and people do not get sick on schedule, how can this be applied to the healthcare industry?

Although the principle of JIT is simple, there are several profound differences between JIT and traditional methods of inventory management. These differences, taken from Freeland and modified for medical applications, are illustrated in Table 1.

In implementing JIT, hospitals drastically reduce the amount of inventory maintained on the premises. They may even completely eliminate all but the most critical items from stockage. The number and frequency of shipments from the supplier to the hospital are increased and lead-time is drastically reduced. Uncertainty (variance) is reduced or virtually eliminated. The use of competition between suppliers as a price control tool is reduced in favor of cooperation and partnership between hospital and supplier.

The most basic benefit of JIT materiels management is a large reduction in the standing inventory (Celley,1986:14). This reduction in inventory results in a one time saving

Table 1. Contrasting Traditional versus JIT Management

TRADITIONAL MANAGEMENT	JUST-IN-TIME PURCHASING
1. Large delivery lot sizes, infrequent deliveries.	1. Small lot sizes based on near term needs. Deliveries are frequent.
2. There are several vendors for each item. Multiple sourcing is used to maintain low prices.	2. As much as possible, orders are consolidated to a single vendor.
3. Large inventories are maintained by the hospital.	3. Little inventory remains at the hospital since deliveries are frequent and on time.
4. Contracts are short-term, with fixed price and quantity. No guaranteed repeat business.	4. Contracts are long-term, with variable price and quantity. Performance insures continued business.
5. Minimal information exchanged between supplier and buyer.	5. Extensive, continual exchange of information.
6. Geographic proximity of supplier is not important for supplier selection decision.	6. Geographic proximity of supplier considered very important.

(Modified from Freeland, 1991:45)

equal to the costs of possession for that level of inventory.

> In one hospital the implementation of a stockless inventory system resulted in a decrease in official inventory from $550,000 to $7,700. Other areas of savings were: reduction in warehouse space; fewer supply related full-time employees; and fewer purchase orders generated. In total over one million dollars in savings were realized. ("Koley's", 1988:51)

Increases in the overall quality/service is another benefit reported by companies using JIT (Ansari, 1990:45). In a hospital, increases in supply quality/service equate to better service to the healthcare provider and thus the patient. Pettus states that although a hospital may implement a JIT system to save money, the success of the system must be measured by marked improvements in service levels (Pettus, 1990:71).

Previous research by Captain Thomas Harkenrider indicates that military, specifically Air Force, hospitals are capable making the change to Just-In-Time. Before a full implementation of this policy could be initiated several concerns regarding wartime requirements need to be addressed (Harkenrider, 1991:81). However, several of the principles of JIT, i.e. increased predictability, are met by the dedicated truck program.

Customer Service

Improving the flow of materiels to the customer is vital for organizational success. Therefore customer service has assumed greater importance (Byrne, 1992:169). One of the benefits emphasized by JIT proponents is increased quality of service (Ansari, 1990:45). A study of 450 organizations showed that improved service reliability increased customer satisfaction and more responsive order fulfillment helped their customers cut inventories dramatically (Byrne, 1992:178). A component of the dedicated truck program is the regular delivery schedule of supplies reducing the customer's uncertainty about delivery.

Lead-time effects customer service as well as inventory levels. It is clear that shorter lead-times reduce safety stock related costs. In addition, a reduction in lead-time variability results in increased reliability and the potential reduction of safety stocks (Gerchak, 1991:191).

Quality in logistics includes timely and reliable delivery (Byrne, 1992:180). For many logistics organizations, service is defined as regular, on-time delivery and is one of the main components of customer satisfaction. Reliability is another key element of customer service (Bradley, 1991:80; Muller, 1991:40). Based on these studies, the scheduled delivery of supplies provided by the dedicated

truck program are a marked improvement to customer service over previous methods.

Shipment Methods

DLA uses a variety of different methods of transporting medical supplies to the requesting hospital. The method of choice is based upon several different factors. The most important of these are economy, priority (urgency of need), distance, and size and weight of the package. For routine supply requests the prime method of shipment is "Less-Than-Load" (LTL). LTL is a transportation term indicating the total shipment is less than a 40 foot truckload based on weight or volume (Connelly, 1992).

Under the LTL shipment policy, the DLA depot electronically stores or "banks" MROs for up to eight days until a large enough volume has accumulated to justify a shipment to the geographic area where that hospital is located. The MROs are then printed and become the daily workload. The supplies are pulled from the shelves and prepared for shipment.

The trucking company under contract for that region is notified when an LTL shipment is ready for pick-up. The truck making the pick-up from the depot may have several stops since the shipment does not fill the truck. It

carries the supplies to a freight consolidation warehouse for shipment to another warehouse servicing the local area of the hospital (Connelly, 1992).

This is the method referred to in later sections as the LTL method. In contrast, the method under study is known as the dedicated truck program.

Under this method of shipment requisitions are no longer banked at the DLA depot prior to being processed for shipment. Instead of storing these requisitions to reach a certain volume for a geographic area, they are processed as they are received. Hospitals are grouped into clusters based on combined volume of the cluster and individual hospital geographic location.

A schedule of deliveries is determined based on the combined volume of the cluster and trucks are contracted to pick-up at the depot at a regularly scheduled time and date. The supplies they pick-up are delivered directly to the hospitals in the cluster also at a regularly scheduled time and day. The supplies are not processed by any other warehouses or transferred to any other trucks. The only stops are at other hospitals within the cluster.

Since the dedicated truck is scheduled and not contingent upon a certain weight or volume, shipment costs vary. The depot must pay for a full load (40,000 lbs) regardless of the weight or volume actually shipped. Offsetting this

is the fact that full load rates are lower than LTL rates allowing a lower break-even point for the program (Connelly, 1992).

DLA currently estimates a savings of $200 per truck and projects an annual savings of $750,000 after full implementation. Another benefit, reduction in the percent of supplies ordered by the hospital on a high priority requiring alternate, more expensive, shipping methods, is expected but more difficult to enumerate (DLA, 1992).

Lead-time Components

The Defense Logistics Agency Integrated Data Bank (DIDB) collects and stores information about every requisition received by DLA. Each requisition is tracked from receipt of the requisition at DLA until the requesting hospital acknowledges receipt of the materiel. This allows researchers to break the process down into discrete components.

This research is concerned with the components referred to as depot process time and materiel in-transit time. Depot processing time, for the purposes of this research, is defined as beginning on the MRO transaction date and ending on the shipping date. Depot processing time includes the bank time as well as the time required by the depot to

process the MRO, pull the supplies, consolidate and package them for shipping, and arrange for transportation.

Materiel In-transit time begins on the shipping date and ends upon hospital acknowledgment of receipt. It is encompasses both the time required for the transportation system (military, commercial or contracted) to move the supplies from the depot to the requesting hospital, as well as time for the hospital to process the receipt.

Figure 2. Total Processing Time Components.

Initial Surveys

The dedicated truck program was initiated in December 1991 using the Washington, DC area as the official test site. The Mechanicsburg depot set up a cluster consisting of Malcom Grow, Bethesda, and Walter Reed Medical Centers. Due to the large quantities of supplies ordered by these facilities the schedule consisted of three deliveries a week (DLA, 1992).

A preliminary customer survey of these facilities was conducted 30 days after the dedicated truck program began. Responses to the survey indicated perceived reductions in

lead-time from 25-45 days prior to the program to an average of 6-10 days for these facilities. Data collected by DLA also indicated a dramatic change in the lead-time although not as great as the previous survey. The DLA data looked solely at the depot processing time, consisting of bank, storage, transportation, and materiel in-transit time, accounting for some of the difference between their figures.

According to DLA the lead-time was 7.7 days prior to the dedicated truck program and dropped to 4 days after its adoption. The DLA data showed that bank time actually increased slightly, while storage time, time awaiting transportation, and materiel in-transit time decreased (DLA, 1992).

Summary

Research question one dealt with effect upon inventory levels. It has been shown that based on the research of other experts in the field of inventory management, reductions in lead-time and lead-time variance have a clear effect upon inventory levels. Reduction of lead-time and lead-time variance are an integral part of JIT practice. Under full JIT implementation, inventory levels maintained at the hospital are reduced drastically to a minimum level or eliminated completely. Incrementally reductions in

inventory levels are also possible as lead-time is reduced and reliability increased.

Research question two asked how customer service was effected by the program. In response to this reliability has been shown to be a key factor in customer service and vital to achieving customer satisfaction. In this light, the regularly scheduled deliveries that are an integral part of the dedicated truck program are critical to maintaining customer service and satisfaction.

The third research question dealt with the lead time components to be measured. The component breakdown used to measure the actual results of the dedicated truck program resulted in three measurements. The first component, depot processing time, is measured from the MRO date, established by DPSC upon transmission to the depot, until the date it is released to the transportation section, the ship date. The second component, shipping time, is measured from the ship date until the requesting hospital processes the materiel, acknowledging receipt. A third measure is included combining the results of the two individual components and called the total processing time.

To follow these results the next chapter examines the methodology used to answer the remaining three research questions. It discusses the experimental design and examines the statistical analyses used to study and manipulate the model.

III. Methodology

Introduction

This chapter addresses the methodology used to conduct the research. It is divided into four sections. The first part reviews the purpose and the specific questions this research addresses. New terms and the meaning of acronyms used in this chapter are also listed here. The second section discusses the experimental design, how the data was collected and the variables used in the model. The third section examines the model and the statistical analyses used to study and manipulate it. The final section describes analysis used to answer each of the research questions.

Purpose

The literature review addressed the first three research questions of this study. Briefly, it established that a reduction in lead-time and lead-time variance should allow a reduction in overall inventory levels and specifically in safety stock levels. The influence of lead-time on reliability and, consequently, on

customer service was established as a major factor. Finally, the lead-time components of the DLA supply system affected by the dedicated truck program were determined and defined.

Three research questions remain to be answered:

4. Did a measurable decrease in lead-time occur in the components affected by the new program?

5. Did a measurable decrease in lead-time variance occur under the new program?

6. If a decrease in the lead-time or lead-time variance has occurred, can these be attributed to the implementation of the dedicated truck program, or can they be explained by other means?

In order to discover the answers to these questions, an analysis of data from actual shipments of materiel is necessary. The focus of this chapter is the methodology used to answer these questions.

Definitions. Some of the terms and acronyms used in this chapter are reviewed here.

Military Standard Requisitioning and Issue Procedures (MILSTRIP) provide a system for requesting supplies and requisition status within DOD supply systems (AR 725-50, 1988: 6-1).

Military Standard Transportation and Movement Procedures (MILSTAMP) provide a format for controlling the

transportation of supplies and equipment within DOD (AR 725-50, 1988: 6-1).

Inventory Control Point (ICP) is the agency charged with the inventory management functions of the commodity. In the case of medical materiel, this is the Defense Personnel Support Center (DPSC) in Philadelphia Pennsylvania.

Dedicated Truck (DT) is the "new" method of transporting medical supplies from the depot to the customer. It is based on a contract for regular, direct shipments of medical materiel from the DLA depot to the requesting hospital. The effectiveness of this program is the subject of this study.

Less than Truckload (LTL) is the "old" method of transporting medical supplies from the depot to the customer. Under this method, medical materiel is shipped on an irregular basis through a contractor who may intermingle these shipments with others for the same general geographic location, and may make several trans-shipments prior to delivery.

Materiel Release Order (MRO)is an electronically transmitted document from the ICP to the depot instructing them to release and ship an order.

Model Design

Models Used in the Study. This study was originally designed to use a single model. However, problems encountered with confounding interactions, to be discussed later in this chapter, necessitated the use of two separate models. For the sake of simplicity each of these will be discussed in this section.

Full Model. The first model, Figure 3, consists of a 2x2x6 blocked factorial design. The independent variables, which are explained later in this chapter, are method (LTL, DT), window (pre- and post-conversion), and the blocking variable is hospital pair. This partitioning of the data results in a total of 24 cells for each of the three dependent variables being measured. The number of observations in each of the 24 cells are not equal. They range from a low of 64 observations to a high of 1568 observations.

This is the primary model used as it facilitates the study of main effects and allows for the testing of interactions between the factors. The model however, has a limitation in that statistical software package used will support only comparisons between class variables. Since the analysis of simple main effects became necessary due to confounding interactions, it was necessary to construct a second model.

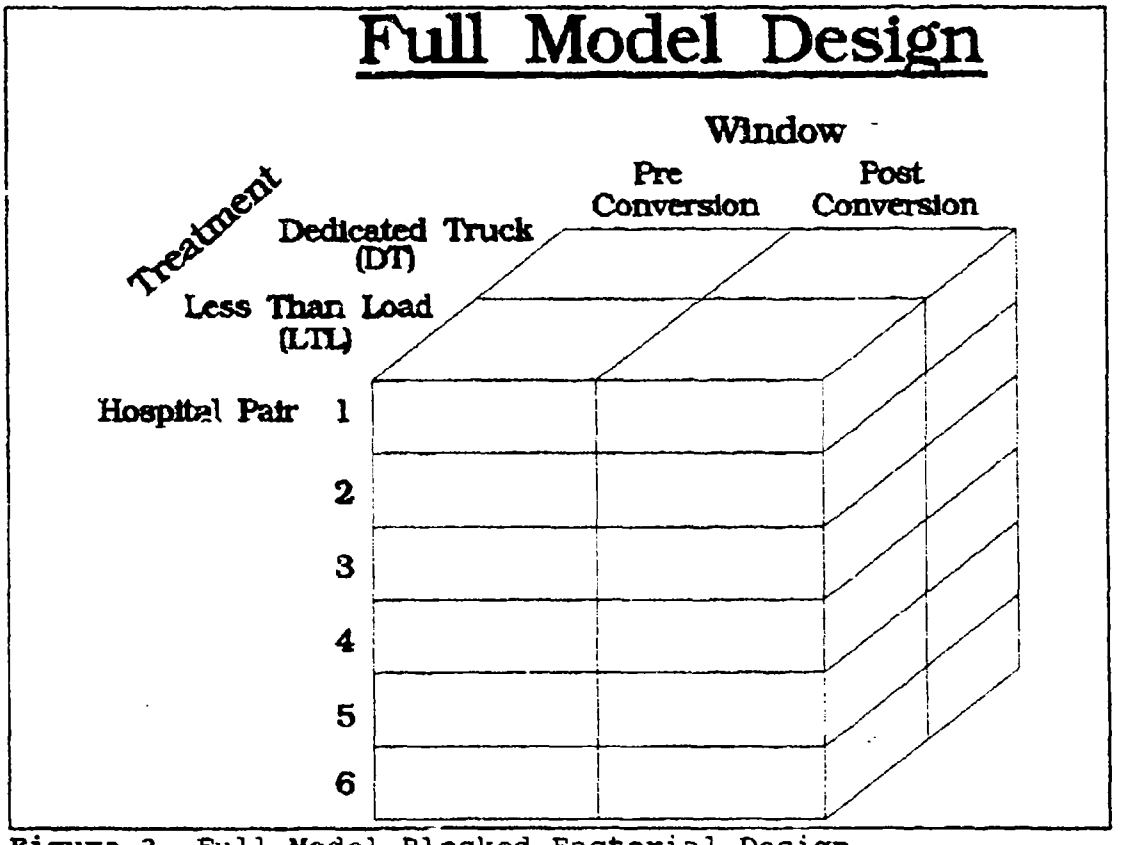

Figure 3. Full Model Blocked Factorial Design.

Alternate Model. The second model, referred to as the alternate model, combines the two independent variables of Treatment and Window into one variable called group. Group then has one of four values, LTL Before, LTL after, DT before and DT after. This is an equivalent arrangement which results in the same 24 cell partitioning of the data, has the equivalent R^2 and sums of squares of the full model. The advantage of this model is that it allows for the examination of simple main effects via pairwise comparisons. An illustration of the partial model is at Figure 4.

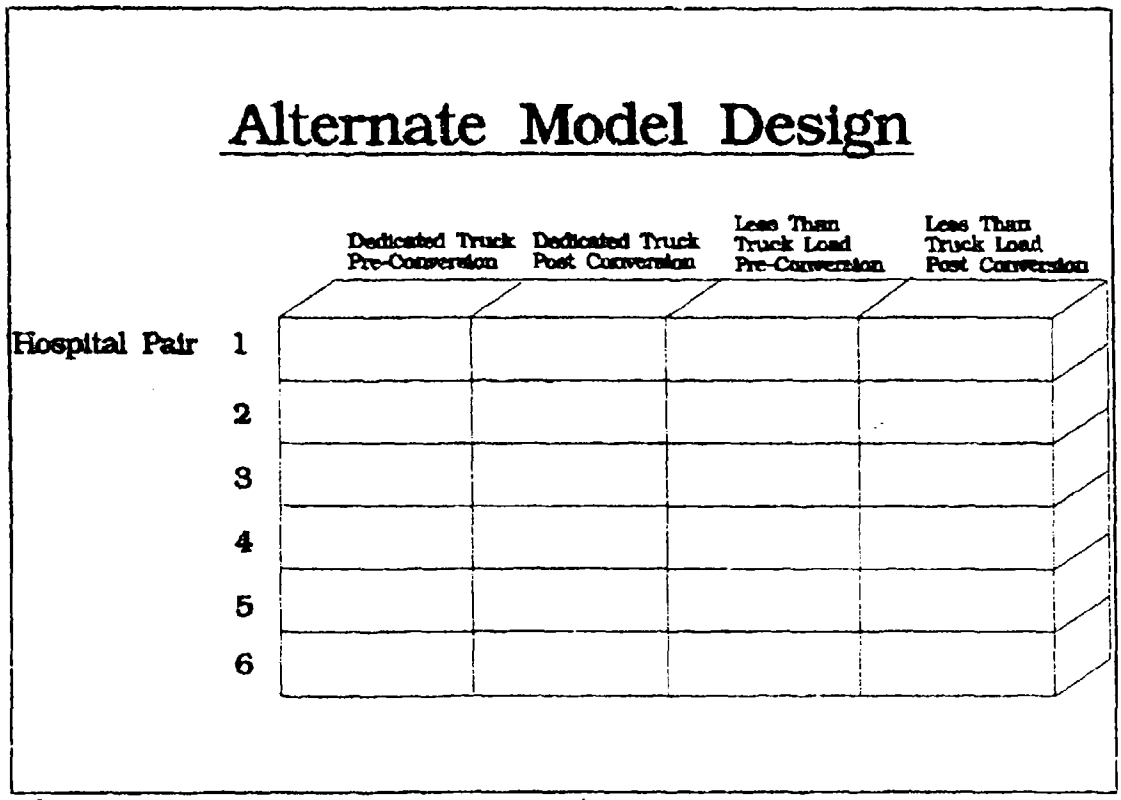

Figure 4. Alternate Model Design.

Research Methodology

"Experimental design is the plan for assigning experimental conditions to subjects and the statistical analysis associated with the plan." (Kirk, 1982:1). It includes determination of experimental units, independent and dependent variables, nuisance variables, and the method of assigning treatments. True experimental design requires that the subjects be randomly selected and the treatment be randomly assigned (Kirk, 1982:2). This research is conducted using a quasi-experimental design since neither the subjects nor the treatments could be randomly assigned. It consists of an observational study over time.

Population. The population for this experiment is all routine priority shipments made from DLA depots to military hospitals for stocked medical materiel during the period 30 June 1991 to 31 December 1992. Only routine priority requisitions are included because methods for the calculation of lead-time (order-ship time) and safety level stocks are based on standard requisitioning rather than emergency (high priority) requisitioning. The inclusion of high priority shipments in the experiment would skew the results in a manner inconsistent with the purpose of this research.

Sample. The sample consists of all routine priority shipments made during the stated time period to 16 selected

military hospitals. Eight of the hospitals selected underwent the change to dedicated truck method of shipment during the period of December 1991 to September 1992. This group of hospitals serves as the test group. Hospitals within the test group are individually matched to eight military hospitals which did not convert to the dedicated truck method of shipment during that period (some converted after the test period). This second group serves as the control group.

Since the design of this experiment includes the use of a control group it was preferable to pick control and test groups that are as similar to each other as possible (Campbell, 1966:48). Accordingly, the match between test hospital and control hospital is based on three major factors: distance from depot to hospital, volume of materiel shipped, and servicing depot. These are described in more detail later.

The range of sample data collected for each pair of hospitals was governed by the date of the test hospital being placed on the dedicated truck program. A fifteen-day window both before and after the conversion date was eliminated to control for conversion turbulence. All routine priority requisitions with an MRO date within a ninety-day period prior to the conversion window were collected as pre-conversion window data for both the test and control hospital. A similar ninety-day period following

the end of the conversion window was identified as the post-conversion window and data collection was performed.

Data Source. Two sources were used to collect data for this experiment. The first was the Defense Logistics Agency Integrated Data Bank. Access to this information was provided to us by DPSC. Our second source was the Army Logistic Control Agency (LCA) which is charged with capturing and maintaining status and control information on all requisitions submitted by Army activities through DOD channels.

Data Set. The observations in each data set were processed to insure that each observation met the following criteria:

1. Completeness - Each observation was checked to insure that it contains an activity designator, shipping depot code and all three dates required by the study: MRO date, shipping date, receipt date. Observations with one or more missing elements were eliminated from the data set. This was the largest cause of elimination of observations, and in fact, Naval hospitals were completely eliminated from the study due to incomplete records.

2. Appropriateness - Records were checked to insure they were appropriate for the study. Records were identified as inappropriate if they were:

a) shipped to activities other than the ordering activity.

b) not routine priority shipments.

c) not orders for materiel, i.e. status cards.

3. Uniqueness - Duplicate records were identified and eliminated.

4. Incorrect depot - Records were checked to insure that the shipments originated from the activity's designated supporting depot. Shipments which were made to an activity from depots other than the activity's supporting depot were eliminated from the data set since these would confound the data by crossing the normal geographic boundaries.

Tables 2 and 3 show a brief breakdown of the two data sets received.

Table 2. DLA Preliminary Data Set

Data Set One: DLA Integrated Data Bank (DIDB)	
Total observations	89,753
Status requests (non-requisitions)	-2,129
Incomplete observations	-55,344
Inappropriate observations	-2,285
Outside of windows	-17,320
Other than supporting depot	-2,226
DLA Preliminary Data Set	**10,649**

Table 3. LCA Preliminary Data Set

Data Set Two: Army LCA file	
Total observations	119,763
Duplicate observations	-9,050
Incomplete observations	-26,271
Inappropriate observations	-1,476
Outside of window	-46,712
Unmatched hospitals	-17,489
Other than supporting depot	-6,114
LCA Preliminary Data Set	**12,651**

Upon completion of all data checks the two data sets were combined and duplicates were removed. The 14,873 remaining observations constituted the preliminary data set for this study. Initial review of the data set revealed additional problems. Two hospital pairs, of the original eight pairs, each had an empty data cell for one of the pair. The data, consisting of 1,788 observations, for those two hospital pairs was eliminated leaving a data set of 13,085 observations for six hospital pairs.

Questionable Observations. In order to identify observations which might not accurately reflect the processing time, observations were examined from an operational viewpoint prior to any statistical analysis. The examination of the preliminary data set was based on the

three dependent variables: depot processing, materiel in-transit time, and total processing time, and resulted in additional deletions from the data set.

All records which had a negative value for any of the dependent variables were considered to be erroneous and eliminated from the data set.

Observations having materiel in-transit times of greater than 30 days were eliminated based on the authors' combined 25 years of logistics experience. When in-transit status has been received against a requisition and the materiel is not received within 30 days, it is standard procedure to close the requisition, and place a trace on the shipment. Therefore, any entry for a receipt date which results in a materiel in-transit time in excess of 30 days is considered to be unreliable.

The final cluster of data examined included all observations with materiel in-transit time or data processing time in excess of 15 days. These observations were examined for any discernable pattern. Although no pattern was noted for the majority of observations, one group of observations appeared to have been caused by other than normal processing procedures.

This group of requisitions was from Malcolm Grow Medical Center. The group consisted of 93 requisitions, each of which was released for processing on 11 October 1991 (91284), shipped on 24 October 1991 (91297), and receipted

on 13 November 1991 (91317). The depot processing and materiel in-transit times were identical for all requisitions in this group indicating a possible deliberate delay by the depot before shipping and a delay in processing the receipts by the medical center. Due to the passage of time, no documentation could be found to support this theory. However, the large number of requisitions, each processed in the same time frame are so inconsistent with normal depot and unit operations that it was decided to remove them from the data set.

The remaining extreme observations showed no pattern and no evidence of unusual circumstances was detected so they remained in the data set.

Dependent Variables. The dependent variables examined in this experiment are depot processing time, materiel in-transit time, and total processing time. Depot processing is measured from the transmission date (from DPSC to the depot) to the date the shipment is made. Materiel in-transit time begins with the ship date and includes actual transit time, plus base and hospital supply processing time. Total processing time is the combination of the two times.

All three of the dependent variables are measured in days. Since they are quantitative, and have an absolute zero they can be treated as ratio data.

Independent Variables. In creating the model for this experiment we used three categorical independent variables. The first independent variable, method, indicates whether the data are from a hospital under the old less-than-truckload method (LTL), or the new dedicated truck program (DT). The second independent variable is window, the Before level indicates the data are pre-conversion, while the After level indicates the data are post-conversion.

The third independent variable, a blocking variable, is the hospital pair and it has six levels. Every hospital has a number of characteristics such as servicing depot, distance from that depot, and service affiliation that may affect depot processing and materiel in-transit time. Therefore, each hospital in the test group was matched for these characteristics as closely as possible to allow the affects of some of these characteristics to be controlled.

Confounding Variables. The four major factors considered in selecting control and test hospitals and leading to the hospital pairing are also the major confounding variables. They are distance from depot to activity, volume of materiel shipped, servicing depot, and seasonality. A further description of each is in order.

Distance from depot to activity has an obvious and unavoidable effect upon the materiel in-transit time. Hospitals are paired so that both hospitals could receive

deliveries within the same time frame i.e. one days travel or two days travel.

Volume of materiel shipped may affect the total processing time in several ways and is very difficult to control. Characteristics of the hospital such as workload, type of facility, and service affiliation could impact the average volume of materiel shipped to a facility.

Workload of the facility has a direct impact on the quantities of materiel required to perform that work, and subsequently the amount of materiel which could be ordered and shipped from the depot.

Type of facility is another characteristic that may affect the quantity and type of supplies ordered. A small hospital offers a limited variety of medical specialties compared to a medical center where, in addition to a greater diversity of specialists, several medical teaching programs may be located. This greater diversity affects both the quantity and type of materiel required by the medical center. To a lesser degree, this variation also occurs between hospitals of different sizes.

Service affiliation (Air Force, Army or Navy) is a third characteristic that may affect the volume of materiel ordered from the DLA system. There is some variation between the ordering policies of the three services and their reliance upon DLA supplied materiel (Pease, 1992).

Servicing depot may have a profound effect upon depot processing time. Potential differences in operating procedures, personnel strength and experience, and shipping contractors as well as physical layout and equipment may affect the results of the experiment. There are three main depots involved in handling medical supplies. Mechanicsburg, PA services the eastern region of the continental U.S., Memphis, TN services the central region, and Tracy, CA services the western region. Figure 5 outlines these regions.

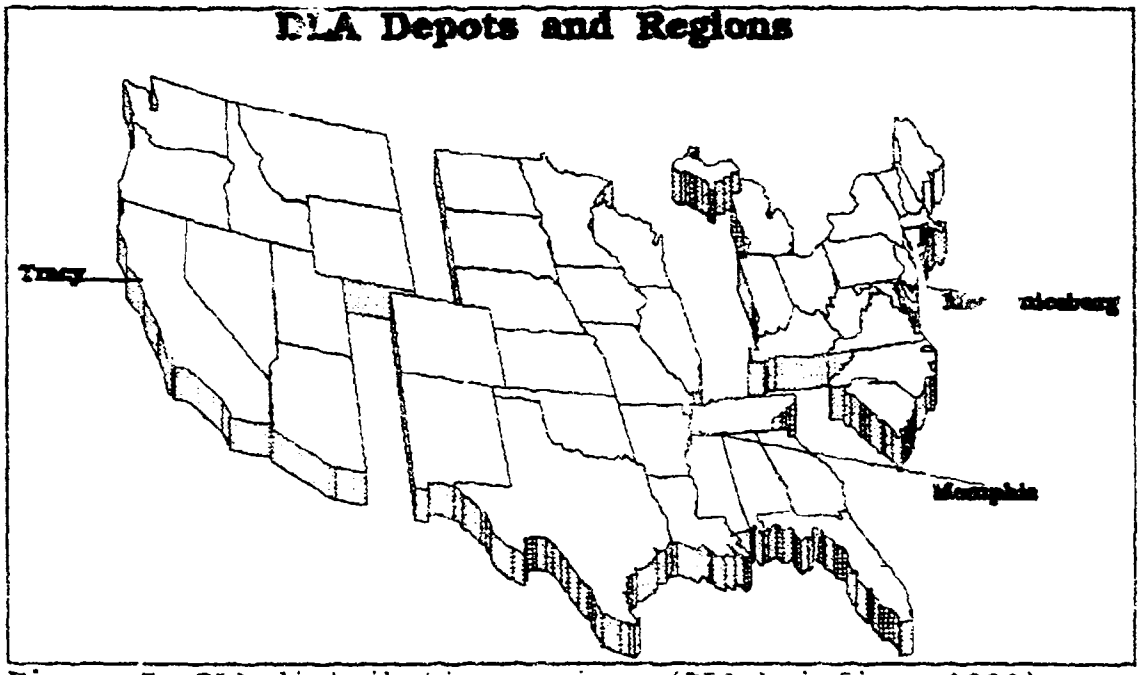

Figure 5. DLA distribution regions (DLA briefing, 1992)

Time of year (seasonality) can effect the volume of materiel being shipped, the depot's ability to process, and the contractors time to deliver the materiel. The effects

of summer hires, winter storms, holidays, flu epidemics and other seasonal variations on the processing and in-transit times must be controlled. Since conversion from LTL to DT occurred at different times throughout the year these variations cannot be controlled for within the hospitals included in the test group. By using data from the same time period in the test and control hospital, seasonality is controlled for, to some degree, in the pairing.

Internal changes at individual hospitals provide other potential confounding variables. Installation of new automation systems, manpower changes, and even physical facility improvements are examples of major events that may have occurred during the course of the experiment and had a significant affect on the dependent variables under study. However, these events could not be accounted for within the scope of this experiment.

Another potential source of variance is the effect of changing from the less-than-truckload method to the dedicated truck method on the frequency of shipments for each hospital. Under less-than-truckload the shipment frequency for a particular hospital is partially determined by the volume of all the hospitals in the geographic region. However, in designing the clusters, geographic region is only one factor considered. A cluster may consist of hospitals from different regions and may include more or fewer hospitals than the original geographic region.

Therefore, the effect of changing from shipping to a geographic area to shipping to an individual cluster is exclusive to the facility in question.

This may best be explained by an example contrasting the affect of changing to dedicated truck on hospitals A and B. Hospital A is a large hospital and is in an area that has a high volume of supplies going to it. This high volume will trigger frequent shipments to the region. On changing to dedicated truck hospital A is included in a cluster with other large hospitals in the region and receives shipments three times a week. Hospital A will probably not experience a large change in its processing time.

In contrast, hospital B is a small hospital and in a geographic region with a low volume of supplies. Shipments to this region and subsequently to hospital B are not very frequent. Hospital B however, is on a direct route to a distant group of hospitals with a high volume and is included in this cluster for dedicated truck. Hospital B now receives shipments on the same schedule as the large hospitals in the cluster and therefore probably experiences a large change in its processing times.

As the above example illustrates, this factor is unique to each hospital. It has the potential to significantly affect the dependent variables of the experiment but is not predictable and therefore not controlled in this experiment.

Selection of Test and Control Groups. Several constraints exist in the selection of medical facilities for this experiment. The first constraint is the availability of data. The latest data available are for the first quarter of fiscal year 1993 (October - December 1992). In designing this experiment the decision was made to include ninety days of post- and pre-conversion data. This period provided a large sample size while allowing the use of some hospitals as controls prior to their own conversion to the dedicated truck program. It also restricted the selection of medical facilities for the test group to those converted to dedicated truck no later than 15 September 1992 (the last day that allowed the collection of ninety days of post-conversion data).

After selecting the medical facilities which could be used in the test group, all other facilities were considered as possible matches to be used as controls. In order to compare facilities a database was created combining information about the workload, geographic location, driving distance from the depot, servicing depot, service affiliation, and type of facility for every military hospital in the continental United States. This information was obtained from the individual depots and the U.S. Medicine Directory 1992-93: Major Federal Medical Treatment Facilities. Although most criteria, such as service

affiliation, type of facility, and distance, are easy to obtain, workload is far more complex.

Workload Determination. The volume of supplies, based on the relative workload, is one of the criteria used in matching test hospitals, with those used as controls. Relative workload was chosen to illustrate the volume of supplies to eliminate individual differences in the method of determining the workload.

The two most common indicators of workload are the average daily bed occupancy and the number of clinic visits. However, it is nearly impossible to find two hospitals with the same ratio of bed occupancy and clinic visits. As an alternative these two indicators were combined into one figure to allow a comparison of overall workloads.

In order to combine these indicators, it is necessary to find a conversion factor to equate clinic visits with beds occupied in terms of the relative quantity of supplies required for each. Various experts at the Army Health Services Command and the Air Force Surgeon General's Office were consulted and recommendations ranged from a factor of 6:1 to 10:1. Since no reliable factor could be found, a different approach was required.

All hospitals in the database were ranked in ascending order of daily bed census and the rankings were recorded. The hospital with the smallest daily bed census was ranked number 1 and the largest ranked 125.

The database was then subjected to a sensitivity analysis to determine if the rankings, and subsequent relative workload, were sensitive to the clinic visit to bed occupancy conversion factor. Since the recommended conversion factors were estimates, a wider range of conversion factors, 3:1 and 25:1, was used in estimating equivalent workloads for clinic visits and beds occupied. The workload figures were calculated using the following equation:

Workload = (Average daily bed occupancy * 365) + (Annual clinic visits * conversion factor)

After calculating the workload with one conversion factor, the resulting figures were again ranked from 1 to 125. The ranking for each hospital was noted, and the calculation and ranking repeated for the second conversion factor.

The relative workload rankings of each potential hospital pair were examined. Those with less than a 10% deviation for both workload estimates were considered to have equivalent workloads.

An examination of Table 4 will show that this is true for all hospital pairs except pair two. Although hospital pair two varies only 7% using the 25:1 conversion factor it varies 17% at 3:1. Despite this pair two was retained in the study because it met all other criteria and was the only

hospital pair served by the Tracy depot for which data was available.

A final database was created combining all of the factors used in matching the hospitals: service affiliation, type of facility, servicing depot, distance, and relative standings based on workload conversion factors. Hospitals were then selected and placed in the control group as best matches for the test hospitals using all the listed factors. Appendix A contains all the factors used in creating the hospital pairs.

The data set was divided into six hospital pairs and each data set was further subdivided into four separate cells representing the two levels of method and window. This division of data resulted in the 24 separate cells that were used in the analysis.

Statistical tool

An Analysis of Variance (ANOVA) using the General Linear Models (GLM) approach was chosen as the method of analysis for the data in this study. The SAS software system (version 6, copyright 1990), was used to conduct the analysis. SAS is a registered trademark of the SAS Institute.

ANOVA was selected over Regression for two reasons; the

Table 4. Hospital Pair Information

Pair Number	Service	Size	Depot	Group	Delivery Distance	Work-load 25:1	Work-load 3:1
1	AF	C	PA	T	1 day	109	108
1	AF	C	PA	C	1 day	112	110
2	AR	C	TR	T	1 day	111	102
2	AR	C	TR	C	2 day	120	123
3	AR	L	ME	T	1 day	102	112
3	AR	L	ME	C	1 day	105	106
4	AR	M	PA	T	1 day	72	67
4	AR	M	PA	C	1 day	69	61
5	AF	S	ME	T	1 day	23	29
5	AF	S	ME	C	1 day	21	24
6	AR	L	ME	T	2 day	106	113
6	AR	L	ME	C	2 day	110	116

Key: Size: Small, Medium, Large, Medical Center
Depot: MEmphis, TN Mechanicsburg, PA TRacy, CA
Group: Test, Control

independent variables in this study are categorical, and ANOVA does not require any assumptions to be made regarding the statistical relationships between the variables (Neter and others, 1990:518).

The General Linear Model was selected in particular because the experimental design is unbalanced. Although the ANOVA procedure in SAS processes data more efficiently than GLM, GLM is recommended where direct computation of the sum of squares fails as in the case of an unbalanced design (Freund and Littel, 1985:85).

Plan of Analysis

A standardized plan was developed to study each of the dependent variables. This plan of analysis includes a listing of descriptive statistics by group, testing assumptions of the design, modifying the data as required, and checking the model for confounding interactions. Since two- and three-way interactions were found to be significant the analysis was concluded by studying simple main effects using pairwise comparisons (Neter and others, 1985:805-8).

Differences in variance are also of interest in this experiment and are examined using the Bartlett test and simple comparison.

Descriptive Statistics as a Group. Since the intent of this research is to be able to make inferences concerning the effect of the Dedicated truck program on the dependent variables, the data was initially collapsed across the six blocked hospital pairs. A listing of the group sizes, means and variances are in Tables 5 to 7. Similar listings for individual cells may be found at Appendix C.

Table 5. Descriptive Statistics for Total Processing Time

Group	n	Mean	Variance
LTL Before	3149	11.023	35.457
LTL After	3630	11.724	42.726
DT Before	2154	10.863	45.558
DT After	3999	10.372	25.839

Table 6. Descriptive Statistics for Depot Processing Time

Group	n	Mean	Variance
LTL Before	3149	4.94	16.88
LTL After	3630	5.664	16.424
DT Before	2154	4.955	15.563
DT After	3999	6.058	12.5

Table 7. Descriptive Statistics for Materiel In-Transit

Group	n	Mean	Variance
LTL Before	3149	6.084	13.274
LTL After	3630	6.06	17.259
DT Before	2154	5.908	19.518
DT After	3999	4.315	10.772

Histograms were also done on each of these groups to determine if there were gross departures from normality for any of the three dependent variables. Examination showed that the data is not normally distributed. The histograms for the four groups are at Appendix B.

Underlying Assumptions of the Design. There are two groups of assumptions which need to be met in order for the results of this study to be valid. These are associated with either the F statistic in the ANOVA model or with the design of the experiment itself. Since the two groups of assumptions overlap they are contained in one list. These assumptions are:

1. That the data are distributed normally.

2. The errors are independent, and are normally distributed within each population with a mean of zero.

3. The experiment contains all the treatment levels of interest.

4. That the samples were randomly selected and treatments randomly assigned.

5. The population variances and error term variances must be homogeneous between the cells. (Kirk, 1982: 74-75)

Determination of Normality. The histograms of the individual cells were very similar to those of their corresponding group. From these and the results of the Wilkes-Shapiro test in the SAS procedure, PROC Univariate, it was concluded that the data is not normally distributed. The individual cell scores for the Wilkes-Shapiro ranged from 0.69 to 0.96. with a score of 1.0 indicating normality. An examination of the charts at Appendix B shows that of the three dependent variables, depot processing time appears the least normal and total time is the closest to normal. The histograms done in this section demonstrate that although neither the group nor the cell distributions are normal, they are not radical departures from normality.

All cell distributions are similar in shape in that they are unimodal and are skewed to the right. Since research has demonstrated that the F statistic is very robust with respect to normality, and mild to moderate

deviations from normality will not effect the power or significance of the test, the ANOVA model is still appropriate (Kirk, 1982:75).

Error Terms. Assumption two, errors are independent and are normally distributed within each population with a mean of zero, was tested by running an ANOVA using the full experimental model to generate residuals. These residuals were then separated into cells and subjected to the same descriptive tests as the sample populations above. The output demonstrated that the means of the residuals in each cell were zero, and although the distributions were not normal they were not radical departures from normality.

The independence of the error terms must be established by reviewing the properties of the data. The selection of shipments in any one group was completely independent of every other group since each shipment is unique in regards to requesting hospital, materiel and date. Nor could a selection of a shipment affect the selection of samples in another group. As a result both the samples and errors are independent by definition (Reynolds, 1993).

Treatment Levels of Interest. Assumption three requires that the model contain all treatment levels of interest. The treatment levels in the experiment are less-than-truckload and dedicated truck. Other methods of

shipment are not commonly used for routine shipments and are therefore not of interest to this study.

Randomness. Since this is an observational study, assumption four could not be met completely, but this is addressed in the design of the experiment and in the data collection. The samples were not randomly selected, but do consist of the total population of usable records for each hospital and window.

In this experiment, the treatments were not randomly assigned to the sample populations. The purpose for the random assignment requirement is to "distribute the idiosyncratic characteristics of subjects over treatment levels so that they will not selectively bias the outcome of the experiment" (Kirk, 1982:76). This is partially addressed in the nature of the blocked design by testing hospitals in matched pairs thereby decreasing variance within groups.

Homogeneity of Variance. The last assumption requires that the variances of the error terms in each cell are equal. The Bartlett test was used to test for equality of variance. A complete listing of the Bartlett test results is at Appendix E.

The H_o that the variances are equal was examined at a 95% confidence level with 23 degrees of freedom for each of the three dependent variables. The Chi Square test statistic for this test was 35.17. Since the test statistic

for the equality of the variance was greatly exceeded in all three cases, the H_o was rejected and the variances were considered to be statistically different. The results of the test for each sample population are at Table 8. Research has demonstrated that for samples of unequal sizes, moderate differences in homogeneity of variance can have a marked effect on test significance. Therefore, further treatment of the data was required (Kirk, 1982:77).

Table 8. Bartlett Test Results

Variable	Variance Range	Test Statistic	Result
Total Processing	8.14 - 84.39	1606	Reject H_o
Depot Processing	3.13 - 45.01	2863	Reject H_o
Materiel In-Transit	4.17 - 26.09	1166	Reject H_o

Method of Improving Model. To overcome the problems with failing to meet the assumption that the variances of the error effects were equal, a weighted ANOVA was performed. In this procedure the terms in the sums of squares are weighted by the inverse of the variance of that cell according to the number of observations in that cell (Hoaglin and others 1991:285). In effect, this places more weight on those observations that have a smaller variance than those with a larger variance. The best linear unbiased

estimator (BLUE) is obtained when the weights are inversely proportional to the cell variances (SAS/STAT, 1990:927).

To insure that the weighting procedure corrected the problem with heteroscadacisity, weighted and unweighted ANOVA's were performed on all three data sets and the results compared. The critical portions of the output are listed in Tables 9 to 10.

Comparison of weighted and unweighted ANOVA's

Table 9. Total Processing Time ANOVAs

Test	Total Sum of Squares	Model Sum of Squares	Error Sum of Squares	Mean Square Error	R^2	F Value
Unweighted ANOVA	471,610	113,876	357,733	27.714	.241463	178.65
Weighted ANOVA	17,073	4,165	12,908	1.0000	.243994	181.13

Table 10. Depot Processing Time ANOVAs

Test	Total Sum of Squares	Model Sum of Squares	Error Sum of Squares	Mean Square Error	R^2	F Value
Unweighted ANOVA	199,770	29,750	170,020	13.17	.14892	98.20
Weighted ANOVA	15,390	2,483	12,907	.99991	.16131	99.29

Table 11. Materiel In-Transit ANOVAs

Test	Sum of Squares	Model Sum of Squares	Error Sum of Squares	Mean Square Error	R^2	F Value
Unweighted ANOVA	197,689	56,708	140,891	10.922	.28686	225.75
Weighted ANOVA	19,532	6,624	12,908	.99998	.33914	288.01

An examination of the tables shows that the F value and the R^2 for total and depot processing times increase slightly while the values for materiel in-transit times increase significantly. These increases reflect a greater portion of the variance as being taken up by the weighted model as compared to the unweighted. In addition, there are large reductions in the sum of squares and the Mean Square Error drops to 1, indicating that the weighting has resolved the problem of unequal cell variances.

Full Model Weighted ANOVA. A full weighted ANOVA was run for the each of the dependent variables. The F scores from the ANOVAs indicated that all interactive terms used in the models were significant. The three-way interactions of the blocking variables with both of the independent variables confounds the ability to test for main effects across the hospital pairs and necessitates the study of simple main effects by conducting pairwise comparisons.

Testing of individual hospital pairs. To eliminate the confounding effects of the block treatment interactions found above, weighted ANOVA's were performed on each

hospital pair using the alternate model in order to judge simple main effects. The pairwise comparisons however, are taken from the unweighted ANOVAs on the same model. This is done because the "GLM procedure in SAS uses the weighted means is if they were unweighted means when performing multiple comparison tests. The statistical interpretation of such tests is not well understood." (SAS/SDAT: 913). Use of the unweighted ANOVA to perform pairwise comparisons does not affect the significance of the test.

Pairwise comparisons were then done for all possible sets of pairs using the Tukey procedure for joint estimation. Tukey's was chosen because of its conservative results and robustness with regards to unbalanced cell sizes. The results of the Tukey test, using the unweighted means, were more conservative further increasing the validity of the results. All tests were performed at a 95% confidence level.

Analysis for Research Questions

After analyzing the data to test the assumptions of the design it was necessary to perform further analysis to determine the answers to the research questions. Each question and the analysis used to answer it is discussed in detail in the following sections.

Tests for Research Question Four. To determine if lead-time decreased for hospitals converting to the dedicated truck program the Tukey's test was used. Due to the three-way interaction, the ANOVA test for main effects could not be used as a reliable measure. Therefore simple main effects were measured even though they are specific to the pair tested and cannot be generalized to other pairs. The hypothesis being tested was: $H_0 \quad \mu_1 = \mu_2 = \mu_3 = \mu_4$.

Tests for Research Question Five. One of the objectives of the research is determine if the variances of the processing times were affected by the dedicated truck program. Research to find a reliable test for quantifying differences in variances within a given confidence level was unsuccessful. Therefore another approach was developed.

The variances of the post-conversion test cells were subtracted from the pre-conversion cells for the same hospital. This gave a simple estimate of the change in variance.

Tests for Research Question Six. In order to isolate the effects of the dedicated truck program on the dependent variables, additional analysis was necessary. The results of the analysis of the control hospitals were used to eliminate the effects of universal changes on the test hospitals.

Determining the Effect on Lead-Time. In an analysis by hospital pair using the Tukey procedure, the

mean of each group is the result of a simple main effect, i.e. a single treatment level with a single window (time) level. In order to obtain estimates of the effects of the program alone, it was necessary to subtract out the effect of the window factor. Three separate estimates were done on the data from each pairwise comparison. These are the most conservative estimate, simple difference of the means and least conservative estimate.

1. Most conservative estimate. This is the smallest estimate of the true difference in means that could be a result of the Dedicated truck program as it impacts on the processing time for each hospital pair. It is calculated by taking the Simultaneous Lower Confidence Limit (SLCL) of the difference in processing times of the Dedicated truck pre-conversion and post-conversion cells minus the Simultaneous Upper Confidence Limit (SUCL) of the difference in processing times of the Less than load pre- and post-conversion cells.

$$(DB\ SLCL - DA\ SLCL) - (LB\ SUCL - LA\ SUCL)$$

2. Simple difference of means. This is a less conservative estimate, calculated by simple subtraction of the differences of the means.

$$(DB\ \mu - DA\ \mu) - (LB\ \mu - LA\ \mu)$$

3. Least conservative estimate. This is the estimate of the largest true difference in means that could be a result of the Dedicated truck program as it impacts on the processing time for each hospital pair. It is calculated by taking the Simultaneous Upper Confidence Limit of the difference in processing times of the dedicated truck pre- and post-conversion cells minus the Simultaneous Lower Confidence Limit of the difference in processing times of the less-than-truckload pre- and post-conversion cells.

(DB SUCL - DA SUCL) - (LB SLCL - LA SLCL)

Testing for simple main effects allows for a simple comparison of results. This comparison allows us to eliminate the effects of some of the confounding variables from our estimates of the effect of lead-time.

Determining the Effect on Lead-Time Variance.

In order to estimate differences in variance caused by the dedicated truck program the variances were subjected to a Bartlett test. This established the homogeneity or lack thereof for both the test and control hospitals, pre- and post-conversion. To eliminate the effect of universal changes in variance additional steps were taken.

The variances of the control hospitals were treated in the same manner as the test hospitals, subtracting post-conversion variances from pre-conversion variances. These results were then subtracted from the simple estimate of

change in the matching test hospital. The remaining variance may be attributed to the effect of the dedicated truck program.

Summary

This chapter discussed the research questions and objectives, model, experimental design, and statistical methods that were used to study the data. In the Chapter Four, Analysis and Findings, the results of the statistical analysis are discussed. The three dependent variables are discussed individually.

In Chapter Five the conclusions and recommendations resulting from the research are explored.

IV. Analysis

Introduction

This chapter discusses the analysis of the data collected for this study. The chapter is divided into three basic sections. The data is analyzed in accordance with the plan discussed in Chapter III. The first section gives the results of the analysis for the dependent variable total processing time. Sections two and three, in turn, will then give the results of the analysis for the two components of total processing time: depot processing and materiel in-transit times.

Analysis Of Total Processing Time

Significance of Full Model. The results of the full model weighted ANOVA for total processing time are at Table 12. These results clearly demonstrate that the model was significant with an observed significance level of Pr > F is .0001. The coefficient of determination for the ANOVA (R^2) shows that almost 25% of the variance in the data was explained by the model. Although this is clearly a significant portion of the total variance it also indicates

that 75% of the variance in the data was due to factors other than those included in the model. Some of the potential sources of variance that could not be controlled for were discussed in Chapter III. A copy of the full SAS output for this and all subsequent ANOVA's may be found at Appendix D.

Table 12. Full Model ANOVA for Total Processing Time

Total Sum of Squares	Model Sum of Squares	Error Sum of Squares	Mean Square Error	R^2	F Value	Pr > F
17,073	4,165	12,908	1.0000	.243994	181.13	0.0001

Significant Factors of the Model. Table 13 lists the type III sums of squares for all factors and interaction terms in the model. Type III sums of squares, also known as partial sums of squares, were used because they show each effect independent of other effects and are unrelated to cell frequencies (Freund and Littell, 1985:104). An examination of Table 13 shows that all factors except window were significant. More importantly, the table also shows that there is a significant (Pr > F = .0001) three-way interaction between the two independent variables (method, window) and the blocking variable (hospital pair). This three way interaction confounded the ability to test for main effects across the hospital pairs. As a result the

study of simple main effects was conducted. This was accomplished by using the alternate model in performing one-way ANOVA's on each hospital pair and conducting pairwise comparisons using the Tukey test.

Table 13. Significant Factors in Model

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	3.31399	3.31399	3.31	0.0687
METHOD	1	48.73247	48.73247	48.73	0.0001
WINDOW*METHOD	1	30.24129	30.24129	30.24	0.0001
HOSPITAL PAIR	5	1903.40530	380.68100	380.68	0.0001
WINDOW* HOSPITAL PAIR	5	555.56152	111.11230	111.11	0.0001
METHOD* HOSPITAL PAIR	5	459.69756	91.93951	91.94	0.0001
WINDOW* METHOD* HOSPITAL PAIR	5	58.29176	11.65835	11.66	0.0001

Test for Simple Main Effects. The alternate model used in testing simple main effects uses a single factor labeled group which has four levels. Table 14 lists the key used to code each group into the SAS system. These conventions are used throughout the remainder of this study.

Table 14. Abbreviations Used in Tables and Charts

Treatment	Window	Group
LTL	Before	LB
LTL	After	LA
DT	Before	DB
DT	After	DA

Significance of Models. Table 15 contains the results of the ANOVA's done for each hospital pair. An examination of the table will reveal that the models were significant at Pr > F = .0001 for all hospital pairs except pair 5. A re-examination of the data and of the factors used in matching the pairs gave no insight as to why the model was not significant for this pair.

The range of values for the coefficient of determination (R^2) from the preceding ANOVA's mirrored the results of the significance tests with values ranging from less than 1% to almost 20%. Variance taken up by the model for hospital pairs 1, 2, and 6 was substantial and ranged from 13.5% to 19.2%. Variance accounted for by the model for hospital pairs 3, 4, and 5 was considerably less ranging from .8% for pair 5 to 3.1% for pair 3. The low ranges of variance substantiates that some significant sources of variance were not accounted for in the model.

Table 15. Individual Weighted ANOVAs

Hospital pair	n	Model Sum of Squares	Error Sum of Squares	Total Sum of Squares	R^2	F Value	Pr > F
1	3558	842.00	3554	4396.00	0.1915	280.75	0.0001
2	2410	186.63	2406	2965.89	0.1887	186.63	0.0001
3	1774	57.36	770	1827.35	0.0314	19.12	0.0001
4	3085	64.32	3081	3145.32	0.0205	21.44	0.0001
5	574	4.48	570	574.48	0.0078	1.49	0.2153
6	1531	238.95	1527	765.96	0.1353	79.65	0.0001

Pairwise comparisons were done for all possible sets of pairs using the Tukey procedure for joint estimation. Of the six possible contrasts, only three are of interest in this study. These contrasts are: the change between the dedicated truck before and after cells, DB - DA; the change between the less than truck load before and after cells, LB - LA; and a contrast measuring the equivalency of the paired hospitals before the conversion, DB - LB. Using these equations, decreases in processing times are positive values, while increases are indicated by negative values. For reference the full set of comparisons may be found with the accompanying ANOVA output in Appendix D.

Pairwise Comparisons. Table 16 lists the results of each pairwise comparison. Examination of the table reveals a significant decrease in total processing times between DT before and after in hospital pairs 1 (5.99 days) and 6 (2.63 days). Hospital pairs 2 and 4 however, showed significant increases ranging from 1.1 days to 4.3 days while hospital pairs 5 and 3 showed no significant change. The differences in mean processing times noted do not however, give a complete and accurate indication of the effect of the dedicated truck program on total processing times.

Table 16. Tukey's Studentized Range (HSD) Test

Hospital Pair	Group Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
1	DB - LB	0.1000	0.9540	1.8081	***
	DB - DA	5.2108	5.9942	6.7775	***
	LB - LA	1.5877	2.2157	2.8437	***
2	DB - LB	-5.2399	-4.2052	-3.1705	***
	DB - DA	-5.1850	-4.3040	-3.4229	***
	LB - LA	-5.4123	-4.4877	-3.5632	***
3	DB - LB	1.0085	1.8700	2.7316	***
	DB - DA	-0.3100	0.7364	1.7829	
	LB - LA	-0.3649	0.5899	1.5448	
4	DB - LB	0.4267	1.1715	1.9162	***
	DB - DA	-1.8183	-1.0726	-0.3269	***
	LB - LA	-1.2531	-0.5996	0.0540	
5	DB - LB	-1.0685	0.0986	2.4657	
	DB - DA	-0.6251	0.9227	2.4705	
	LB - LA	-0.7179	0.4638		
6	DB - LB	-1.9874	-0.8823	0.2228	
	DB - DA	1.5170	2.6304	3.7437	***
	LB - LA	-1.5710	-0.6484	0.2742	

Key: *** indicates a significant difference.

Effects of Dedicated Truck Program on Lead-Time. In order to obtain estimates of the effect of the dedicated truck program alone, it was necessary to subtract out the effect of the window factor. As stated in the methodology three separate estimates were used. These are the most

conservative, simple difference of the means and least conservative. Table 17 contains these estimates as well as the estimated difference between the means of the dedicated truck and the LTL pre-conversion cells, essentially the difference in processing times between the test hospital and its paired control.

An examination of the table reveals that for hospital pair 1 the estimated effects of the dedicated truck program range from a conservative estimate of decrease of 2.36 days to a maximum estimate of 5.31 days. Hospital pair 6 also experienced a decrease ranging from 1.24 days to 5.31 days. The test results for all remaining hospital pairs pass through zero and are therefore not statistically significant.

Table 17. Estimates of Differences in Means

Hospital Pair	Conservative Estimate	Simple Difference	Least Conservative Estimate	Difference Between Test & Control
1	2.3671	3.7785	5.1898	0.9540
2	-1.6218	0.1837	1.9894	-4.2052
3	-1.8548	0.1465	2.1478	1.8700
4	-1.8723	-0.4730	0.9262	1.1715
5	-2.0706	0.4589	2.9884	N/S
6	1.2428	1.982	5.3147	N/S

Key: N/S - not significant

Differences in Variance. To answer research question five concerning potential effects of the dedicated truck

program on processing time variance, it was necessary to accomplish two tasks. The first was to determine if the variances of the DT before and after cells were equal, and to estimate the true difference in the cell variances.

Equality of Cell Variances. To determine if the cell variances for the DT before and after cells are different, an F test based on the ratio of the sample variances was conducted. Since all cells except those representing hospital pair 5 contained over 120 observations an F statistic using 120 degrees of freedom in both the numerator and denominator (1.35) was used for the test. For hospital pair 5 an F statistic using 110 degrees of freedom in the numerator and 60 in the denominator (1.47) was used. Table 18 shows that the variances of the cells representing the DT before and after conditions for hospital pairs 1,3,5, and 6 were sufficiently different to reject the null hypothesis at $\alpha = .05$. The variances of cells representing the DT before and after conditions for hospital pairs 2 and 4 were not significantly different.

Table 18. F Test for Equality of Variance

Cell	Before	After	Variance 1 / Variance 2	Test results
1 DT	84.38588	10.86390	7.767549	Reject H_0
2 DT	23.73061	23.08262	1.028073	Accept H_0
3 DT	49.74583	22.25703	2.235061	Reject H_0
4 DT	34.81477	35.42451	1.017514	Accept H_0
5 DT	22.62164	8.14657	2.776828	Reject H_0
6 DT	34.20484	11.50566	2.972871	Reject H_0

Key: 1 DT, etc. refers to the converted hospital in pair 1.

Effects of the Dedicated Truck Program on Lead-Time Variance. A technique, similar to that used for differences in mean processing times was used to estimate the magnitude of changes in the variances that could be attributable to the effect of the dedicated truck program. Any changes in cell variance found between DT before and after (DB - DA) were adjusted by any changes that occurred in the control over time (LB - LA).

Table 19 displays the results of the estimated changes in variance. The most dramatic change occurred in hospital pair 1 which experienced a net difference in variance of 78 days. Hospital pairs 2, 3, 5, and 6 also experienced decreases in variance although not to the extent of pair 1. Hospital pair 4 showed an increase in variance of 0.61 days for the DT cells while the control showed a decrease of 6.6 days resulting in a net after conversion increase of 7.23 days.

Table 19. Differences in Variance

Hospital Pair	DB - DA	LB - LA	Difference
1	73.52198	-4.49138	78.01336
2	0.64799	-16.83570	17.48364
3	27.48880	18.58280	8.90595
4	-0.60974	6.56661	-7.17635
5	14.47506	6.63335	7.84171
6	22.69918	11.41123	11.28795

Summary. The preceding analysis of total processing time indicates that there are significant differences in the means and variances of some of the test pairs. The significance of these differences and any inferences concerning the dedicated truck program will be discussed in the next chapter. This concludes the analysis of the total processing time. In the next section results of the analysis of depot processing times are examined using the same procedure.

Analysis Of Depot Processing Time

Significance of Full Model. The results of the full model weighted ANOVA for depot processing time are at table 20. This model was significant with an F value of 98.2 with a Pr > F = .0001. The coefficient of determination

for the ANOVA (R^2) shows that 16% of the variance in the data was taken up by the model. This is less than the value observed for total processing time and indicates that 84% of the variance in the data was due to factors other than those included in the model.

Table 20. Full Model ANOVA for Depot Processing Time

Total Sum of Squares	Model Sum of Squares	Error Sum of Squares	Mean Square Error	R^2	F Value	Pr > F
15,390	2,483	12,907	.99991	.16131	99.29	0.0001

Significant Factors of the Model. The type III sums of squares for all factors and interaction terms in the model are listed in Table 21. An examination of the table shows that all factors except method and the interaction term of window and method were significant with a Pr > F of .0001. As was the case with the previous analysis of total processing time, the table also reveals that there is a significant (Pr > F = .0001) three-way interaction. Due to the confounding three-way interaction the analysis preceded with the study of simple main effects by conducting one-way ANOVA's for each hospital pair and performing pairwise comparisons using the Tukey test.

Table 21. Significant Factors

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	104.401033	104.401033	104.41	0.0001
METHOD	1	3.879586	3.879586	3.88	0.0489
WINDOW*METHOD	1	2.649627	2.649627	2.65	0.1036
HOSPITAL PAIR	5	997.495114	199.499023	199.52	0.0001
WINDOW* HOSPITAL PAIR	5	385.568349	77.113670	77.12	0.0001
METHOD* HOSPITAL PAIR	5	315.248684	63.049737	63.06	0.0001
WINDOW* METHOD* HOSPITAL PAIR	5	46.320035	9.264007	9.26	0.0001

Test for Simple Main Effects. Table 22 contains the results of the ANOVA's done for each hospital pair. An examination of the table will reveal that the models were significant at Pr > F = .0001 for all hospital pairs except pair 6. A re-examination of the data and of the factors used in matching the pairs gave no insight as to why the model was not significant for this pair.

The range of values for the coefficient of determination (R^2) revealed a dramatic decrease in the amount of variance taken up by the model as compared to the analysis of total processing time. The R^2 values for hospital pairs 4 and 6 were less than 1% while the values for pairs 1,3, and 5 were less than 7%. Only in pair 2 was more than 10% of the variance in the data accounted for by the model.

Table 22. Individual Weighted ANOVAs

Hospital pair	n	Model Sum of Squares	Error Sum of Squares	Total Sum of Squares	R^2	F Value	Pr > F
1	3558	229	3553	3783	.061	76.52	0.0001
2	2410	494	2406	2900	.170	164.66	0.0001
3	1774	112	1770	1882	.059	37.26	0.0001
4	3085	19	3081	3100	.006	6.47	0.0002
5	574	37	570	607	.061	12.42	0.0001
6	1531	5	1526	1531	.004	1.81	0.1430

Results of Pairwise Comparisons. Pairwise comparisons were done for all possible sets of pairs using the Tukey procedure for joint estimation. While Table 23 lists the results of the comparisons of interest, the full set of comparisons may be found with the accompanying ANOVA output in Appendix D. Examination of the table reveals a significant decrease in depot processing times between DT before and after of 1.5 days for hospital pair 1. Hospital pairs 2,3, and 4 however, showed significant increases ranging from 0.51 days to 2.8 days. The test results for hospital pairs 5 and 6 passed through zero and were not significant. These differences however, do not give a complete and accurate indication of the effect of the dedicated truck program on depot processing times.

Effects on Depot Processing Time. In order to estimate the effect of the dedicated truck program on depot processing time the results of the pairwise comparisons

found in Table 23 were subjected to the same procedure as were the comparisons of total processing time. Table 24 contains the same three separate estimates of true difference in times: most conservative, simple difference of the means and least conservative.

Table 23. Tukey's Studentized Range (HSD) Test

Hospital Pair	Group Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
1	DB - LB	2.1412	2.6609	3.1806	***
	DB - DA	1.0269	1.5036	1.9802	***
	LB - LA	-0.2446	0.1376	0.5197	
2	DB - LB	-2.0411	-1.3452	-0.6493	***
	DB - DA	-3.4782	-2.8857	-2.2931	***
	LB - LA	-4.1764	-3.5546	-2.9328	***
3	DB - LB	-1.7910	-1.1371	-0.4832	***
	DB - DA	-3.0035	-2.2091	-1.4148	***
	LB - LA	-1.8544	-1.1296	-0.4048	***
4	DB - LB	-0.1746	0.3272	0.8289	
	DB - DA	-1.0178	-0.5154	-0.0130	***
	LB - LA	-0.8744	-0.4341	0.0063	
5	DB - LB	-0.3714	0.4101	1.1916	
	DB - DA	-1.8056	-0.7692	0.2672	
	LB - LA	-0.0877	0.5697	1.2271	
6	DB - LB	-1.6479	-0.7571	0.1337	
	DB - DA	-1.5243	-0.6269	0.2705	
	LB - LA	-0.3231	0.4206	1.1643	

Key: *** indicates a significant difference

An examination of Table 24 reveals that only hospital pair 1 experienced any real decrease in processing times. The test results for hospital pairs 2, 3, 4, 5, and 6 all pass through zero indicating that there was no significant difference in depot processing times associated with the dedicated truck program.

Table 24. Estimates of Differences in Means

Hospital Pair	Conservative Estimate	Simple Difference	Least Conservative Estimate	Difference Between Test & Control
1	0.5072	1.366	2.2248	2.6609
2	-0.5454	0.6689	1.8833	-1.3452
3	-2.5987	-1.0795	0.4396	-1.1371
4	-1.0241	-0.0813	0.8614	N/S
5	-3.0327	-1.3389	0.3549	N/S
6	-2.6886	-1.0475	0.5936	N/S

Key: N/S - not significant

Differences in Variance. To determine if the cell variances for the DT before and after cells are different, an F test based on the ratio of the sample variances was conducted. Table 25 shows that the variances of the cells representing DT before and after for hospital pairs 1, 3, 5, and 6 were sufficiently different to reject the null hypothesis that the variances are equal at $\alpha = 0.05$. The variances of cells representing DT before and after for hospital pairs 2 and 4 were not significantly different.

As used for total processing time, the test statistic for all hospital pairs except pair 5 was 1.35. For pair 5 a test statistic of 1.47 was used.

Table 25. F Test for Equality of Variance

Cell	Before	After	Variance 1 / Variance 2	Test results
1 DT	19.845	9.185	2.160588	Reject H_0
2 DT	12.22	15.458	1.264975	Accept H_0
3 DT	10.601	16.222	1.530233	Reject H_0
4 DT	15.267	13.172	1.159049	Accept H_0
5 DT	12.305	4.174	2.948011	Reject H_0
6 DT	21.192	5.75	3.685565	Reject H_0

Key: 1 DT, etc. refers to the converted hospital in pair 1.

Effects on Depot Processing Time Variance. The effects of the dedicated truck program were estimated by adjusting any changes in cell variance found between the cells representing the dedicated truck program by any changes that occurred in the control over time. Table 26 displays the results of these adjustments.

Hospital pairs 1, 5, and 6 show the largest improvements although the improvement for pair 6 is somewhat offset by a corresponding improvement in the control. Pairs 2 and 3 have significant increases with pair 3 LTL variance improving by 11.9 days. Hospital pair 4's variance decreased for both DT and LTL cells with the larger decrease in the control.

Table 26. Differences in Variance

Hospital Pair	DB - DA	LB - LA	Difference
1	10.66	0.376	10.284
2	-3.238	-0.937	-2.301
3	-5.621	11.964	-17.585
4	2.095	3.699	-1.604
5	8.131	1.834	6.297
6	15.442	4.339	11.103

Summary. The preceding analysis of depot processing time indicates that there are fewer significant differences in the means and variances of the test pairs than was found with total processing time. The significance of these differences will be discussed in the next chapter. This concludes the analysis of the depot processing time. In the next section data for the final component of the total processing time, materiel in-transit time, are examined.

Analysis Of Materiel In-Transit Time

Significance of Full Model. The results of the full model weighted ANOVA for materiel in-transit time are at table 27. This model was significant with an F value of 225.75 with a Pr > F = .0001. The coefficient of determination for the ANOVA (R^2) shows that almost 34% of

the variance in the data was taken up by the model. This is greater than the value observed for both depot and total processing times.

Table 27. Full Model ANOVA for Materiel In-Transit Time

Sum of Squares	Model Sum of Squares	Error Sum of Squares	Mean Square Error	R^2	F Value	Pr > F
19,532	6,624	12,908	.99998	.33914	288.01	0.0001

Significant Factors of the Model. Table 28 lists the type III sums of squares for all factors and interaction terms in the model. An examination of the table shows that all factors were significant with a Pr > F of .0001. As was the case in the previous two analysis, the table also reveals that there is a significant (Pr > F = .0001) three way interaction. Therefore the analysis preceded with the study of simple main effects.

Table 28. Significant Factors

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	211.45944	211.45944	211.46	0.0001
METHOD	1	185.91734	185.91734	185.92	0.0001
WINDOW*METHOD	1	117.23185	117.23185	117.23	0.0001
HOSPITAL PAIR	5	1659.81468	331.96294	331.96	0.0001
WINDOW* HOSPITAL PAIR	5	493.32944	98.66589	98.67	0.0001
METHOD* HOSPITAL PAIR	5	982.55168	196.51034	196.51	0.0001
WINDOW* METHOD* HOSPITAL PAIR	5	175.16677	35.03335	35.03	0.0001

Test for Simple Main Effects. Table 29 contains the results of the ANOVA's done for each hospital pair. An examination of the table will reveal that the model was significant for all hospital pairs at Pr > F = .0001. For this variable the range of values for the coefficient of determination (R^2) was much wider than for the previous variables. The R^2 values ranged from a low of 2.6% in pair 4 to a high of 42.3% in hospital pair 1 indicating that a larger portion of the variance was taken up by the model for this variable than for the previous variables.

Table 29. Individual Weighted ANOVAs

Hospital pair	n	Model Sum of Squares	Error Sum of Squares	Total Sum of Squares	R^2	F Value	Pr > F
1	3558	2601	3554	6155	0.4226	867	0.0001
2	2410	297	2406	2703	0.1099	99.07	0.0001
3	1774	443	1770	2213	0.2003	147.77	0.0001
4	3085	83	3080	3164	0.0263	27.69	0.0001
5	574	75	570	343	.1137	24.38	0.0001
6	1531	599	1527	2125	.2816	199.51	0.0001

Results of Pairwise Comparisons. The results of pairwise comparisons using the Tukey procedure are listed in Table 30. The table reveals that decreases in materiel in-transit times were found in hospital pairs 1, 3, 5, and 6. However, significant decreases in LTL before and after shipments for pairs 1 and 3 may offset the much of the

decrease for these pairs. The remaining hospital pairs, 2 and 4, experienced a slight increase in materiel in-transit.

Table 30. Tukey's Studentized Range (HSD) Test

Hospital Pair	Group Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
1	DB - LB	-2.3099	-1.7069	-1.1038	***
	DB - DA	3.9375	4.4906	5.0437	***
	LB - LA	1.6347	2.0781	2.5216	***
2	DB - LB	-3.5406	-2.8600	-2.1794	***
	DB - DA	-1.9978	-1.4183	-0.8388	
	LB - LA	-1.5412	-0.9331	-0.3250	
3	DB - LB	2.5132	3.0071	3.5011	***
	DB - DA	2.3456	2.9456	3.5456	***
	LB - LA	1.1721	1.7195	2.2670	***
4	DB - LB	0.4079	0.8443	1.2807	***
	DB - DA	-0.9942	-0.5572	-0.1202	***
	LB - LA	-0.5485	-0.1655	0.2175	
5	DB - LB	-0.9606	-0.3115	0.3376	
	DB - DA	0.8311	1.6919	2.5528	***
	LB - LA	-0.6519	-0.1059	0.4401	
6	DB - LB	-0.7409	-0.1252	0.4905	
	DB - DA	2.6370	3.2573	3.8776	***
	LB - LA	-1.5830	-1.0690	-0.5550	***

Effects on Materiel In-Transit Time. In order to estimate the effect of the dedicated truck program on materiel in-transit time the results of the pairwise

comparisons found in Table 30 were subjected to the same procedure as were the previous variables. Table 31 contains the same three separate estimates of true difference: most conservative, simple difference of the means and least conservative.

An examination of Table 31 reveals that hospital pairs 1, 3, 5, and 6 experienced decreases which may be associated with the dedicated truck program. The test results for hospital pairs 2 and 4 pass through zero indicating that there was no significant difference in processing times attributable to the dedicated truck program for these hospital pairs.

Table 31. Estimates of Differences in Means

Hospital Pair	Conservative Estimate	Simple Difference	Least Conservative Estimate	Difference Between Test & Control
1	1.4159	2.4125	3.409	-1.7069
2	-1.6728	-0.4852	0.7024	-2.8600
3	0.0786	1.2261	2.3735	3.0071
4	-1.2117	-0.3917	0.4283	.8443
5	0.391	1.7978	3.2047	N/S
6	3.192	4.3263	5.4606	N/S

Differences in Variance. To determine if the cell variances for the DT before and after cells are different, the cell variances for materiel in-transit time were

subjected to the same F test as were the previous variables. Table 32 shows that the variances of the cells representing the DT before and after conditions for all hospital pairs except pair 2 were sufficiently different to reject the null hypothesis at $\alpha = .05$. The variances of cells representing the DT before and after conditions for hospital pairs 2 were not significantly different.

Table 32. F Test for Equality of Variance

Cell	Before	After	Variance 1 / Variance 2	Test results
1 DT	45.012	4.355	10.335710	Reject H_0
2 DT	8.035	8.063	1.003485	Accept H_0
3 DT	26.925	6.149	4.378761	Reject H_0
4 DT	10.195	16.086	1.577832	Reject H_0
5 DT	5.169	3.099	1.667957	Reject H_0
6 DT	11.950	6.935	1.723143	Reject H_0

Key: 1 DT, etc. refers to the converted hospital in pair 1.

Effects on Materiel In-Transit Time Variance. The magnitude of changes in the variances of the cells that could be associated with the effect of the dedicated truck program were calculated in the same manner as for total and depot processing times.

Table 33 displays the results of adjusting the estimated changes in variance between the before and after DT cells by any changes in variance found in the LTL before and after cells. Hospital pairs 1, 2, 3 and 6 show decreases of between 8 and 42 days while pair 4 shows an

increase in in-transit time of 5 days. Hospital pair 5 experienced a minor increase of 0.5 days.

Table 33. Differences in Variance

Hospital Pair	DB - DA	LB - LA	Difference
1	40.657	-1.350	42.007
2	-0.028	-10.508	10.480
3	20.776	0.054	20.722
4	-5.891	-0.768	-5.123
5	2.070	2.578	-0.508
6	5.015	-3.079	8.094

Chapter Summary

The results of the analysis provided mixed answers to the research questions. The most significant results of the analysis were the changes in variance. Further discussion and analysis of these results are in Chapter V. The conclusions reached by the authors, based on the research and analysis, and their implications for DLA's dedicated truck program are presented.

V. Conclusions and Recommendations

Overview

In 1991, the Government Accounting Office issued a report criticizing the Department of Defense (DOD) for its large standing inventories of medical materiels and the management practices which created them. In response, DOD adopted several new policies in order to reduce the size of its standing inventory and related holding costs. Some of these changes were adaptations of civilian practices such as Just-In-Time (JIT) inventory management. Two of the elements of Just-in-Time are the reduction of lead-time and lead-time variance in the delivery of materiel. These elements play key roles in increasing reliability and result in improved customer service and decreased inventory levels.

Prior to 1992 medical materiel was shipped by the depots to the hospitals by a method known as less-than-truckload (LTL). Under this method only a portion of the truck is contracted for and the shipper is allowed to make stops for freight consolidation and other deliveries. In December 1991 the Defense Logistics Agency (DLA) initiated the dedicated truck program designed to improve the speed and reliability of medical supply deliveries. Under this program transportation is contracted for direct shipment

from the depot to the supported hospital. It was hypothesized that this direct delivery method would reduce both lead time and lead time variability. The purpose of this research was to determine if there were reductions in these factors and if found, could they be associated with the implementation of the dedicated truck program.

This chapter first reviews the methodology used in this study. Next, based on the literature review, expectations of the research are discussed. The actual findings are explained in the third section, followed by the implications and limitations of the research. The chapter concludes with suggestions for further research.

Methodology

Data was collected from the Defense Logistics Agency (DLA) and the Army Logistics Control Agency (LCA) for twelve hospitals. Six of these hospitals had converted to the dedicated truck program. These were matched for servicing depot, distance, size, workload, and service by six hospitals that still received supplies through less-than-truckload shipments. Data was collected for a period of ninety days before and after a thirty day transition window.

The data was broken down to isolate the depot processing time and materiel in-transit elements. A third

category, total processing time, was created by combining the two elements.

The data were analyzed using descriptive statistics, Analysis of Variance, and pairwise comparisons using the Tukey test. Combining the results of these techniques enabled the authors to isolate and estimate the effects of the dedicated truck program on lead-time and lead-time variance.

Expectations

Prior to gathering and analyzing the data the researchers conducted a literature review to determine the impact of converting to a dedicated truck program and to identify variables of interest. This provided answers to the first three research questions of the study.

First, the literature review provided evidence that reductions in lead-time and lead-time variance have a important impact on inventory levels. Research conducted by experts in the field of inventory management demonstrated that any reduction in lead-time should result in an equal reduction in overall inventory, specifically in order-ship time levels. Lead-time variance was proven to have a significant impact on overall inventory levels through the reduction of safety levels. In fact some experts contend

that the effects of lead-time variance on safety levels may be greater than that of lead-time (Chapman, 1986:8).

The basis for this concept lies in the realm of reliability and customer service. This addresses the second research question of this study, establishing whether a relationship exists between lead-time variance, reliability, and customer service. The literature firmly establishes that on-time delivery is a primary objective of reliability. Research done on companies following JIT implementation has shown that reliable deliveries were consistently rated as a major factor in customer satisfaction (Freeland, 1991:45; Byrne and Markham, 1992:171). Therefore regular, reliable deliveries such as those provided by the dedicated truck program should result in increased customer satisfaction.

The third research objective was to identify the components of lead-time affected by the dedicated truck program. These components had to be measurable and identifiable within the data supplied by the DLA and LCA. This definition was required prior to any data gathering or the development of hypotheses. Research of the information contained in the databases revealed key dates (MRO date, ship date, receipt date) which could be used to identify the stages of shipment processing. The measures used in this study, depot processing, materiel in-transit and total processing times were derived from these dates.

Depot processing time was defined as beginning on the date the material release order was transmitted to the depot and ending when the material was ready for shipment. Materiel in-transit begins when the material is ready for shipment and ends when the hospital processes the receipt.

Findings

A statistical analyses was conducted to determine if lead-time and lead-time variance decreased under the dedicated truck program. First, means and variances of the components of lead time were measured and the results contrasted before and after the conversion. Then, to eliminate other factors the changes were compared with those occurring in the control.

Lead Time Reductions. It was anticipated that the activities undergoing the change to the dedicated truck. program would have experienced substantial reductions in their lead-time. However, the results of this research do not support this. Tables 34 through 36 contain summaries of the findings for total processing time and its components. Each table displays the before and after values of the means as well as the estimated difference between them. The final column, adjusted change, contains the estimated difference in means less any differences found in the matched control.

Within the six hospitals that converted to the dedicated truck program there was no reliable pattern of decrease in the total lead-times. Examination of Table 34 reveals that only two hospitals experienced any significant decrease in their total lead-time. Of the other four hospitals in the test, one hospital experienced a small decrease while the remaining three experienced no significant changes. The results also varied within each of the two components with no consistent pattern emerging.

Table 34. Summary of Changes in Total Processing Time

Hospital	Mean Before	Mean After	Change	Adjusted Change
1	14.12	8.12	5.99	3.78
2	10.5	14.80	-4.30	N/S
3	11.01	10.27	N/S	.15
4	9.43	10.50	-1.07	N/S
5	7.53	6.61	.99	N/S
6	12.02	9.39	2.63	1.98

The findings for mean depot processing times are summarized in Table 35. Examination of the table shows that depot processing time decreased for only one of the six converted hospitals in the study. The adjusted changes in the other five hospitals were not significant. Examination of the raw changes indicates that depot processing time increased for hospitals 2, 3, and 4. These changes,

however, were experienced by both the test and control hospitals and were attributed to causes other than the dedicated truck program.

Table 35. Summary of Changes in Depot Processing Time

Hospital	Mean before	Mean after	Change	Adjusted Change
1	6.99	5.47	1.50	1.37
2	4.99	7.87	-2.89	N/S
3	4.34	6.55	-2.21	N/S
4	4.51	5.03	-0.52	N/S
5	3.45	4.22	N/S	N/S
6	5.27	5.90	N/S	N/S

By contrast, the changes in materiel in-transit time, shown in Table 36, were more distinct. Four of the six hospitals showed significant adjusted decreases ranging from 1.23 days to 4.33 days. Larger gross changes were seen however, the decrease experienced by the control hospital offset much of this change. Considering that pre-conversion means ranged from four to seven days, the decreases experienced by the test hospitals were very significant.

During this research no consistent pattern of change within the variables was noted. This eliminated the results being attributed to the performance of any individual depot in the implementation of the program. No pattern of medical center versus hospital, workload or service affiliation emerged from close examination of the analysis either.

Change in mean processing time was not however, the only variable of interest in this study.

Table 36. Summary of Changes in Materiel In-Transit Time

Hospital	Mean before	Mean after	Change	Adjusted change
1	14.12	8.12	5.99	3.78
2	10.5	14.80	-4.30	N/S
3	11.01	10.27	N/S	.15
4	9.43	10.50	-1.07	N/S
5	7.53	6.61	.99	N/S
6	12.02	9.39	2.63	1.98

Changes in Variance. One of the areas of interest in this study concerned the determination of whether a measurable decrease in lead-time variance was experienced by hospitals under the new program. The results of this analysis, summarized in Table 37, are more pervasive than those of lead-time. Overall, five of the six hospitals showed significant decreases. When calculated using the adjusted changes, the hospitals using the dedicated truck program experienced reductions in variance ranging from 32% to 93%. These reductions in variance are significant and will have a major impact on the quality of service the activities are receiving. These effects will be discussed later.

Table 37. Changes in Total Processing Time Variance

Hospital	Variance Before	Variance After	Change	Net Change
1	84.38	10.86	73.52	78.01
2	23.73	23.08	N/S	17.48
3	49.75	22.26	27.49	8.91
4	34.81	35.42	N/S	-7.18
5	22.62	8.15	14.47	7.84
6	34.20	11.51	22.69	11.29

Depot Processing Time. Of the three variables analyzed depot processing was again, the most inconclusive result. Table 38 shows that three of the six hospitals experienced adjusted increases in variance for this component, one hospital as much as 17.6 days. In contrast, three of the six demonstrated decreases between 6.3 and 11.1 days. Again no pattern relating to any of the independent variables was detected.

Table 38. Changes in Depot Processing Time Variance

Hospital	Variance Before	Variance After	Change	Adjusted Change
1	19.85	9.19	10.66	10.28
2	12.22	15.46	-3.24	-2.30
3	10.60	16.22	-5.62	-17.59
4	15.27	13.17	2.10	-1.60
5	12.31	4.17	8.14	6.30
6	21.19	5.75	15.44	11.10

Materiel In-Transit Time. Materiel in-transit time displayed results similar to those of its mean values. The change in variance was much more pronounced and identifiable than for depot processing cime. Four of the six hospitals demonstrated a decrease in variance, one by as much as 42 days. Of the two hospitals experiencing increases in variance, only one was significant.

Table 39. Changes in Materiel In-Transit Time Variance

Hospital	Variance Before	Variance After	Change	Net Change
1	45.01	4.36	40.65	42.01
2	8.04	8.06	N/S	10.48
3	26.93	6.15	20.78	20.72
4	10.20	16.09	-5.89	-5.12
5	5.17	3.10	2.07	N/S
6	11.95	6.94	5.01	8.09

Summary of findings. The research found no conclusive evidence that significant reductions in mean lead-time were experienced due to the dedicated truck program. The changes in variance experienced were more widespread and significant. Five of the six hospitals showed decreases from a moderate 8 days to a highly significant 78 days. On the other hand, the one hospital experiencing an increase in variance had only a seven day change.

It is the judgement of these authors that these analyses do in fact demonstrate that a measurable decrease in lead-time variance did occur and was associated with the implementation of the dedicated truck program.

Implications

There are several implications which may be drawn from the findings of this research. This analysis was unable to conclude that a reduction in lead-time had occurred as a result of the dedicated truck program. However, a reduction in lead-time variance was demonstrated and attributed to the dedicated truck program. Based on the decrease in variance the program has increased reliability and, as a result, improved customer service. The effect upon inventory levels is not clear since no reduction of lead-time itself was proven. Although lead-time variance also affects safety stock, the relationship is less direct and therefore more difficult to measure.

The most unexpected thing that became obvious in the conduct of this research was that the total processing time was never as bad as most materiel managers perceived it. The prevalent belief was that lead-time from the depot averaged as much as 30 days. The research showed that total processing time prior to dedicated truck averaged only

eleven days for both the test and control hospitals. Starting with the misperception of existing service, the regularly scheduled deliveries, combined with the demonstrated decrease of variance and moderate change in service, could have a profound affect on the manager's perception of the service provided under the dedicated truck program.

An additional result of increased reliability is enhancing the ability of the materiel managers at the hospitals to manage. The dedicated truck program facilitates management in a variety of ways. Under the program the manager can incorporate depot deliveries into the daily/weekly work schedule thus increasing the efficiency of the hospital operation.

The program also provides the materiel manager with information he did not have previously. Under the old method supplies did not arrive on a set schedule. Once shipped from the depot the status of the item, and when it would arrive, were subjects of conjecture. If the materiel did not arrive on a given day it was not known how long it would be before it would arrive.

Under the dedicated truck program, the manager knows when his supplies will be arriving. More importantly, if an item is not on the truck, the manager will know with certainty the earliest he may expect the item. The manager may now use this information to decide whether to purchase

the item locally, increase the priority or wait for the next truck.

It is the opinion of the authors that the overall results of the study support the continuation and expansion of the dedicated truck program.

Limitations

Perhaps the greatest limitation in this research was that the number of hospitals for which adequate data was available was limited. This was due to a number of reasons but the three with the largest impact were: time constraints, inability to match some test hospitals with appropriate controls, and incomplete data. Time was a factor because only a limited number of hospitals had converted to dedicated truck early enough for data to be available. For the data which was available, we were not able to find appropriate matches for all test hospitals.

The final limiting factor on the number of hospitals used in the study was incomplete data. Several observations in the data set had to be eliminated because they lacked a key date. This problem resulted in the elimination of all Navy records from the data set thereby eliminating the Navy from this study.

The elimination of the Navy from the database is the second limitation of this study since the results of the study cannot be directly applied to the Navy. However, it can be reasonably expected that Naval medical facilities undergoing the change to dedicated truck may experience the same benefits. The authors feel comfortable in this assertion because the operation of the program and the factors included in this study are external to the hospital.

The final limitation to this study was the small amount of variance explained by the model for some of the test pairs. This indicates that the majority of variance in the lead-time may be attributable to factors other than the dedicated truck program.

Further Research

As often occurs, during the course of this research many other questions were raised. These were outside the scope of this investigation and could not be explored here. However, the answers to some of them have a potentially great impact on the future of DLA and DOD medical logistics.

Incomplete Records. Cited as a limitation, the predominance of incomplete records in both the DLA and LCA databases is an optimal area for further research. The three services varied in the severity of the problem, but it

is an alarming statistic for all. The Air Force, with the best completion rate, still suffered a 42.7% incomplete rate during the periods observed. The breakdown of the observations from DLA, by service, are in Table 40, while Table 41 contains the breakdown for the Army observations received from LCA.

Table 40. DIDB Incomplete Observations

Incomplete observations by service (DIDB)			
	Air Force	Army	Navy
Total observations	28,275	39,303	20,046
Incomplete observations	-12,079	-23,020	-20,045
Complete observations	16,196	16,283	1
Percent incomplete	42.7%	58.6%	100%

Table 41. LCA Incomplete Observations

Incomplete observations, Army (LCA)	
	Army
Total observations	119,763
Incomplete observations	-41,894
Complete observations	77,869
Percent incomplete	35%

Although this problem was widespread within the data for all three services, there were a distinct differences between the individual services. The data in Table 58 shows only one Navy requisition had posted a closing document to the DLA database. In fact, the one closing document was for a request originated by a Navy facility but delivered to an Army address. This problem led to the elimination of all Navy hospitals from the sample. Is there a difference in service regulations that supports this absence of closing documentation or is there an incompatibility in the data processing systems?

Another interesting question is raised by the disparity in the data received from DLA (DIDB) versus that from LCA. The variation from 58.6% to 35% needs no additional testing to prove significance. LCA states that DLA is one of their sources. What additional sources are providing closing documentation for medical materiel requisitions?

From the DLA perspective, what affect does this have on inventory management and billing procedures? It certainly would affect their ability to offer quality customer service since overdue requisitions cannot be differentiated from those received but not closed out in the DLA database. DLA has formed a Process Action Team, as part of their Total Quality Management program, to investigate and resolve some of these questions.

Another factor meriting investigation is the information systems used by each of the individual services to manage their medical materiel. Preliminary screening of the data received for Army facilities indicated an increasing number of complete observations over time. During the same time period as this study covered, the Army was deploying a new inventory management stem to many of its hospitals. The authors speculate that this new system may be responsible for the increase in completed requisitions. However, there were indications that even with this new system some closing documents are still not received or posted to DLA's database.

Differences in Transmission Times to DLA. The initial intent of this research was to measure total lead-time. That is, to measure from the initiation of the requisition by the hospital to receipt by the same hospital. Preliminary investigation of the initiation procedures followed by the different services uncovered some problems. Since it was our desire to measure the effects of the DLA program the decision was made to eliminate any component controlled by the service rather than the depot.

Basically, the three services all follow different procedures in creating a requisition and preparing it for transmission to DLA. In addition, each service and facility may use different methods of transmission to send that requisition to DLA. These differences lead to a great deal

of variation in the length of time between the birth of a requisition and its receipt at DLA. In fact for some requisitions 50% of the total lead-time was prior to receipt of the requisition by DLA.

This sometimes large and widely varying component of lead-time offers an opportunity for further investigation. In a time of downsizing and shrinking budgets, thorough research may lead to a significant change in a very expensive domain.

Other-than-supporting depot shipments. Another discrepancy that became evident during the preparation of the data for analysis was the number of shipments sent from other than the hospital's supporting depot. Since these were the last group of observations eliminated from the data set complete number are not available. However, they represented 26% of the remaining observations after all other categories were eliminated. The cost of shipping one-fourth of all medical materiel, possibly across the country, is staggering.

The basis for many of these shipments is an inventory practice called FIFO - first in, first out. In order to ensure that supplies do not expire on the shelves, leading to their destruction and waste, DLA practices FIFO for their stocks as one inventory regardless of location. So older stocks from Tracy in California would be used to fill an

order from Bethesda Naval Medical Center, despite stocks on-hand in Mechanicsburg, PA.

This problem is exacerbated by the contracting practices. DLA does not have the capability of predicting usage rate by region and contracting for deliveries proportionately. This leads to older stocks becoming concentrated in a region that probably doesn't have a high requirement. And that, in turn, causes cross-country shipments to those regions and hospitals that do have the need.

Further research is needed to establish the true cost of this quality control practice and contrast it to the costs of the additional shipping it causes. An additional area for research is to determine the exact requirements for an inventory management system that could resolve the underlying cause of this problem.

Appendix A. Hospital Descriptions

Activities used in study

Activity name	Method of Shipment	Service	Hospital Type	Servicing Depot	Bed Capacity	Annual clinic visits (1,000)
Hospital pair 1						
Wright Patterson	LTL	AF	M	PA	175	479
Malcom Grow	DT	AF	M	PA	164	473
Hospital pair 2						
Madigan	LTL	AR	M	TR	269	916
Letterman	DT	AR	M	TR	182	402
Hospital pair 3						
Ft Sill	LTL	AR	H	ME	99	522
Ft Campbell	DT	AR	H	ME	88	595
Hospital pair 4						
West Point NY	LTL	AR	H	PA	34	179
Ft Lee	DT	AR	H	PA	37	203
Hospital pair 5						
Chanute ILL	LTL	AF	H	ME	8	103
Moody GA	DT	AF	H	ME	8	110
Hospital pair 6						
Ft Hood	LTL	AR	H	ME	134	765
Ft Carson	DT	AR	H	ME	98	593

Relative workloads

Activity name	Workload @ 3 clinic visits to 1 inpatient day	Workload @ 25 clinic visits to 1 inpatient day	Relative standing @3:1 conversion	Relative standing @ 25:1 conversion
Hospital pair 1				
Wright Patterson	223,382	83,035	110	112
Malcom Grow	217,369	78,780	108	109
Hospital pair 2				
Madigan	403,213	134,825	123	120
Letterman	200,296	82,510	102	111
Hospital pair 3				
Ft Sill	20,9961	57,015	106	105
Ft Campbell	23,0255	55,920	112	102
Hospital pair 4				
West Point NY	72,017	19,570	61	69
Ft Lee	81,104	21,625	67	72
Hospital pair 5				
Chanute ILL	37,219	7040	24	21
Moody GA	39,550	7320	29	23
Hospital pair 6				
Ft Hood	303,655	79,510	116	110
Ft Carson	233,239	59,490	113	106

Appendix B. Histographs by Group

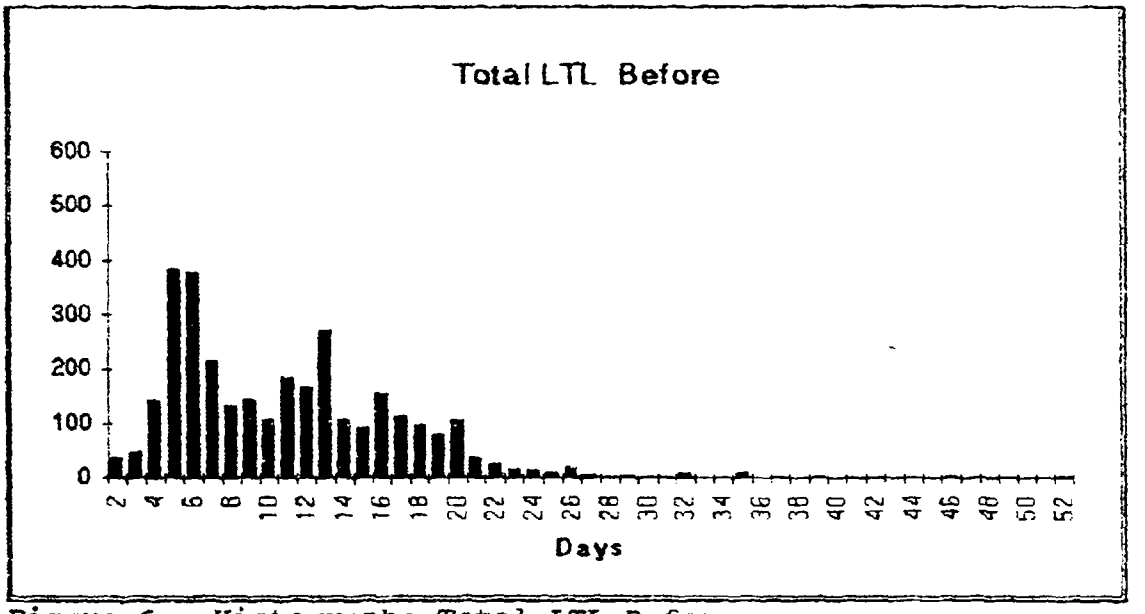

Figure 6. Histograph: Total LTL Before

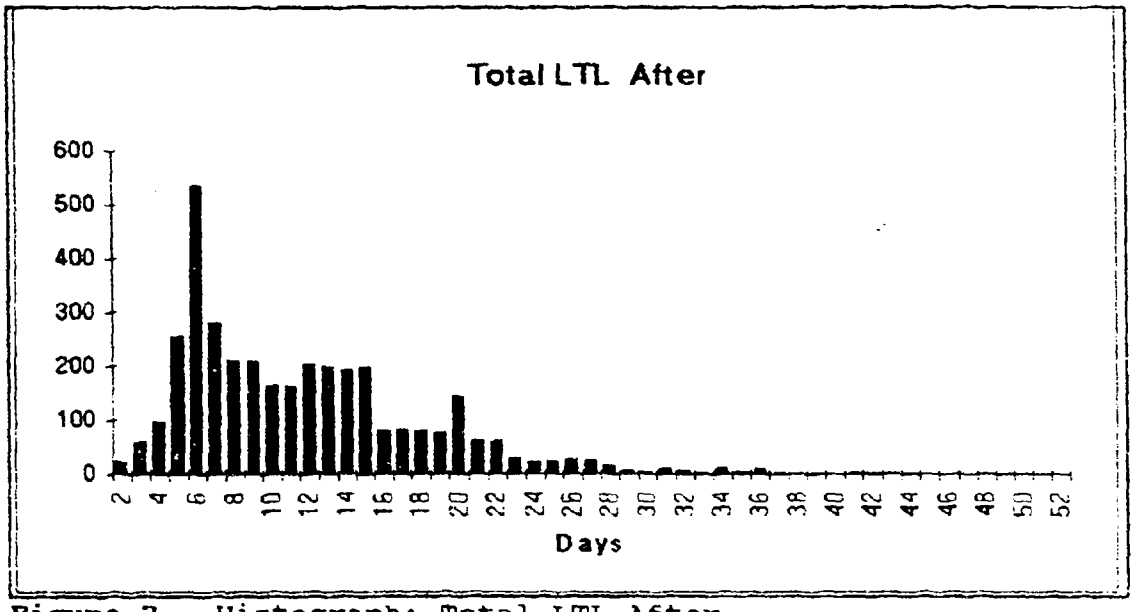

Figure 7. Histograph: Total LTL After

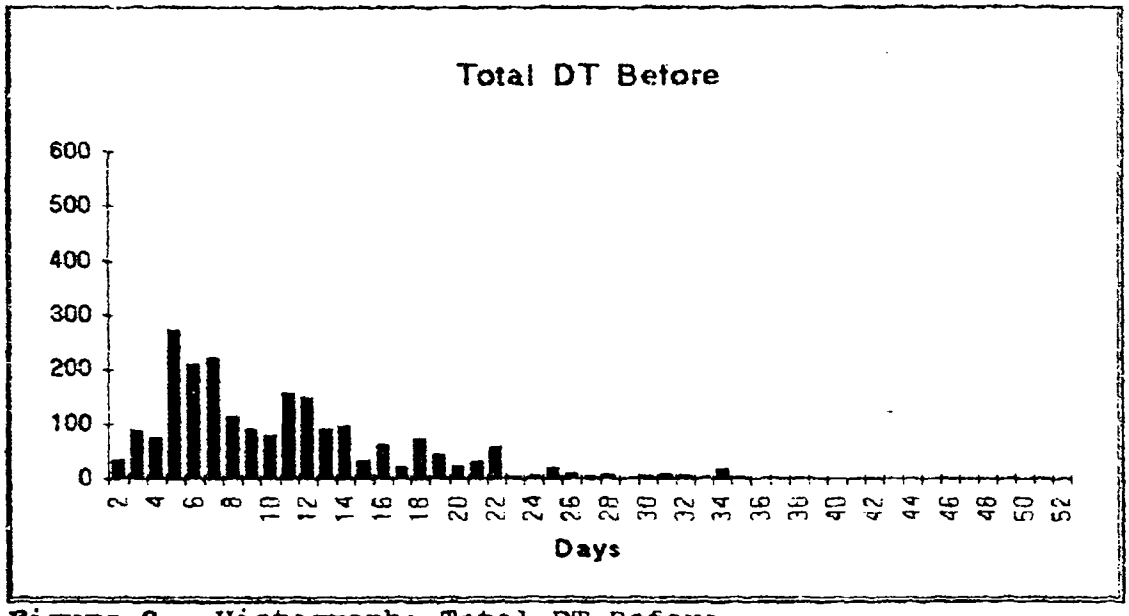

Figure 8. Histograph: Total DT Before

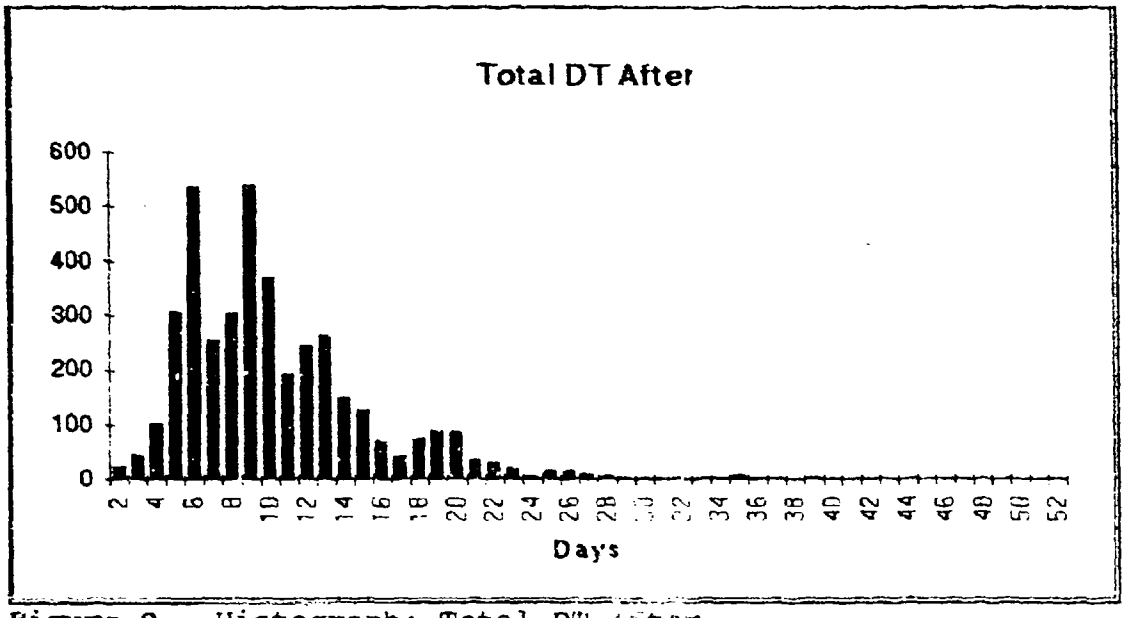

Figure 9. Histograph: Total DT After

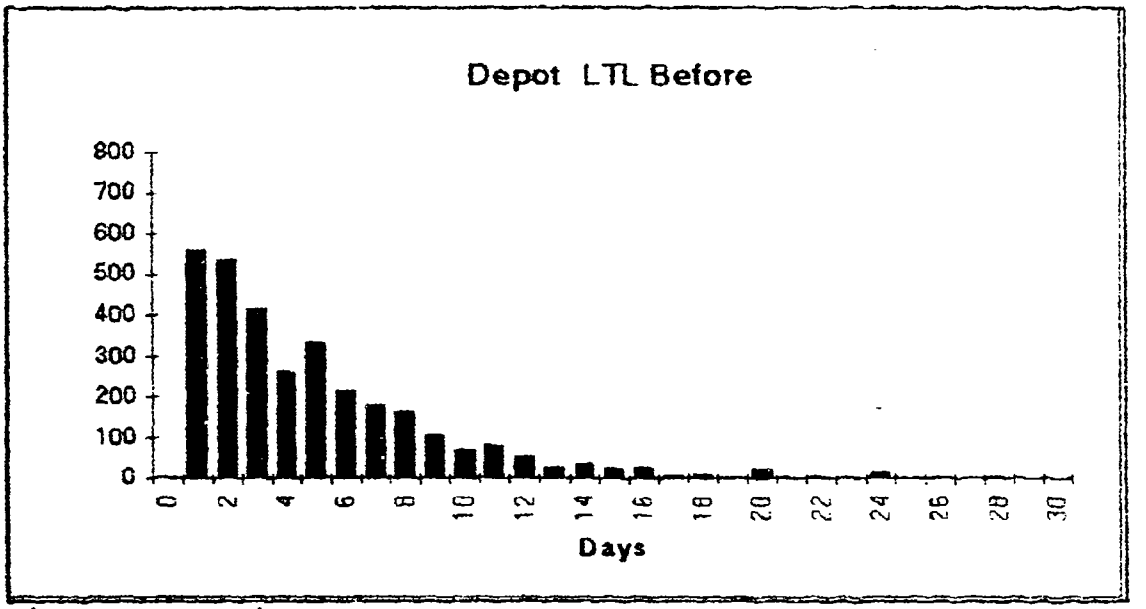

Figure 10. Histograph: Depot LTL Before

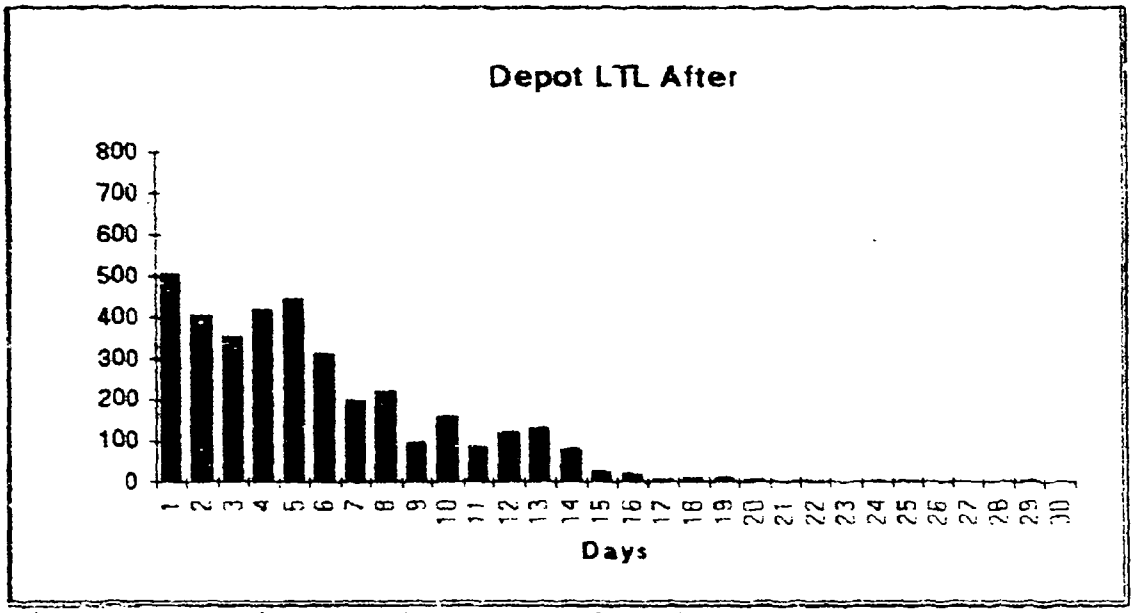

Figure 11. Histograph: Depot LTL After

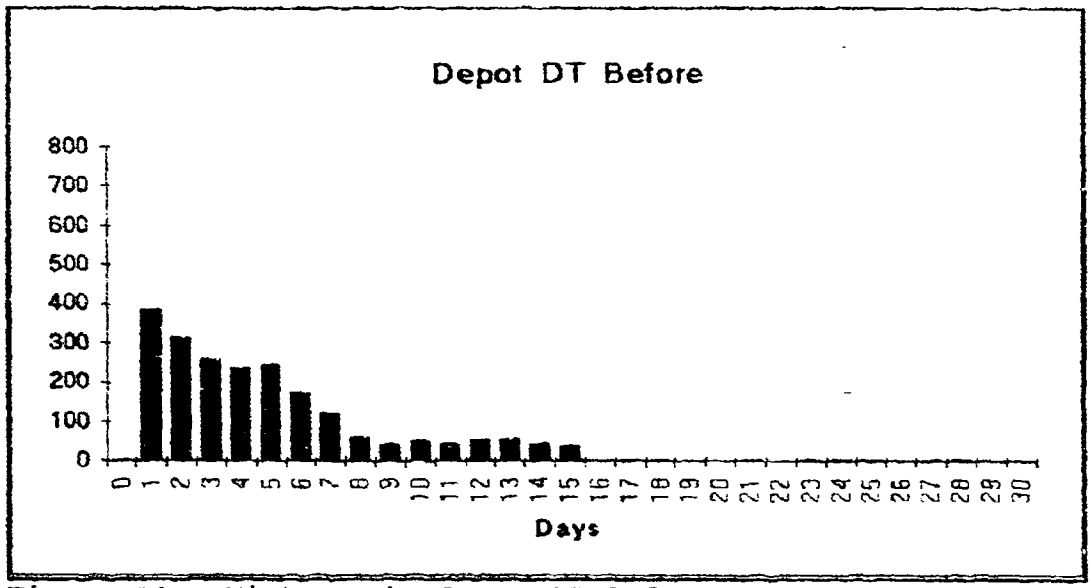

Figure 12. Histograph: Depot DT Before

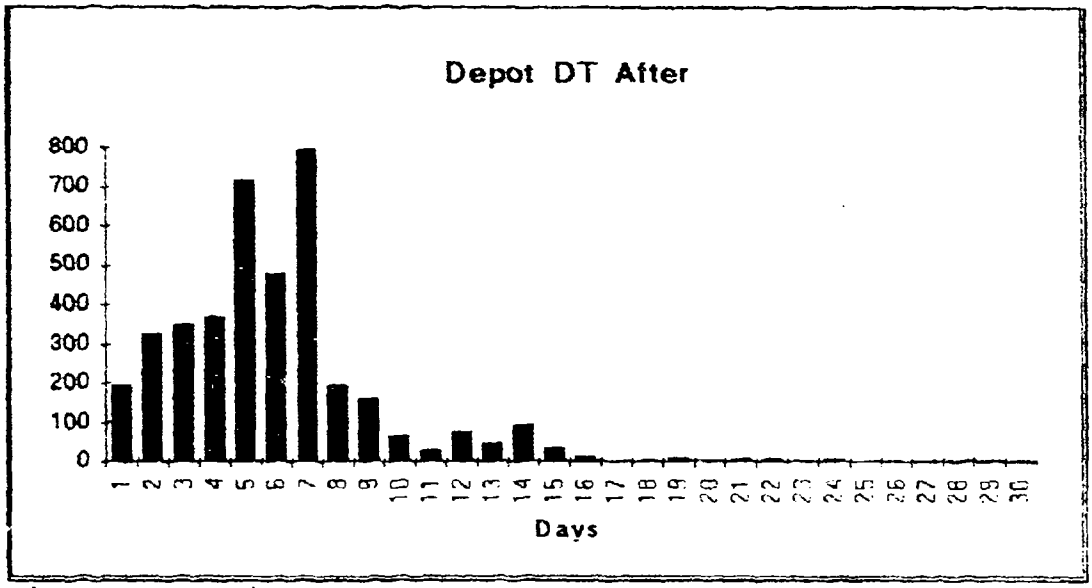

Figure 13. Histograph: Depot DT After

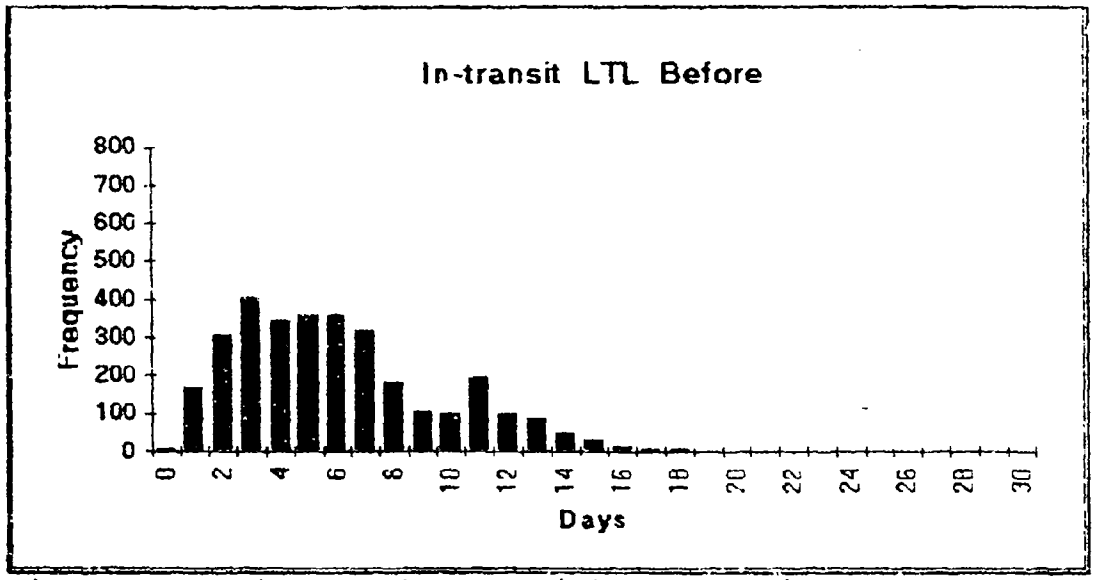

Figure 14. Histograph: Materiel In-Transit LTL Before

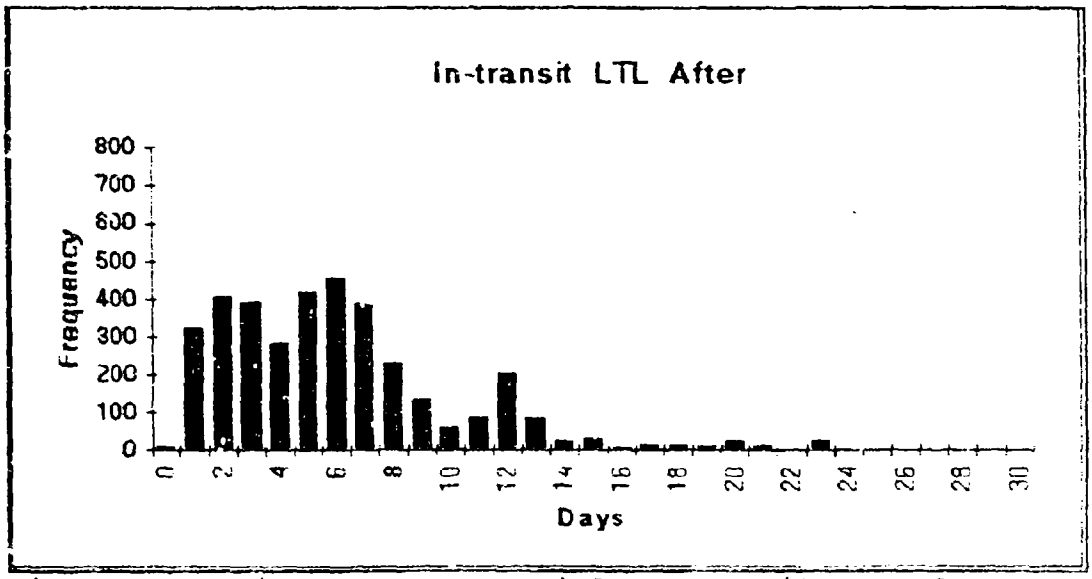

Figure 15. Histograph: Materiel In-Transit LTL After

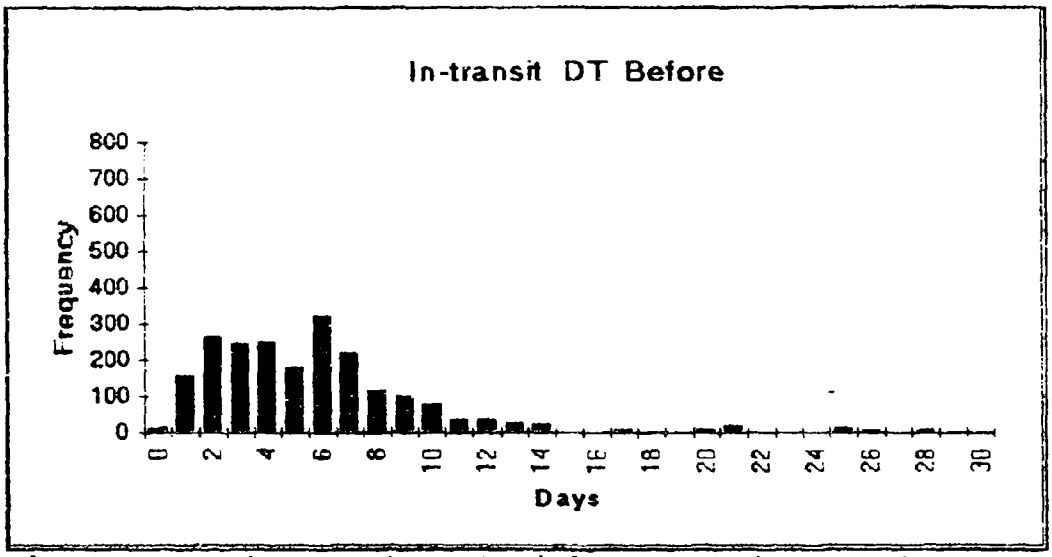

Figure 16. Histograph: Materiel In-Transit DT Before

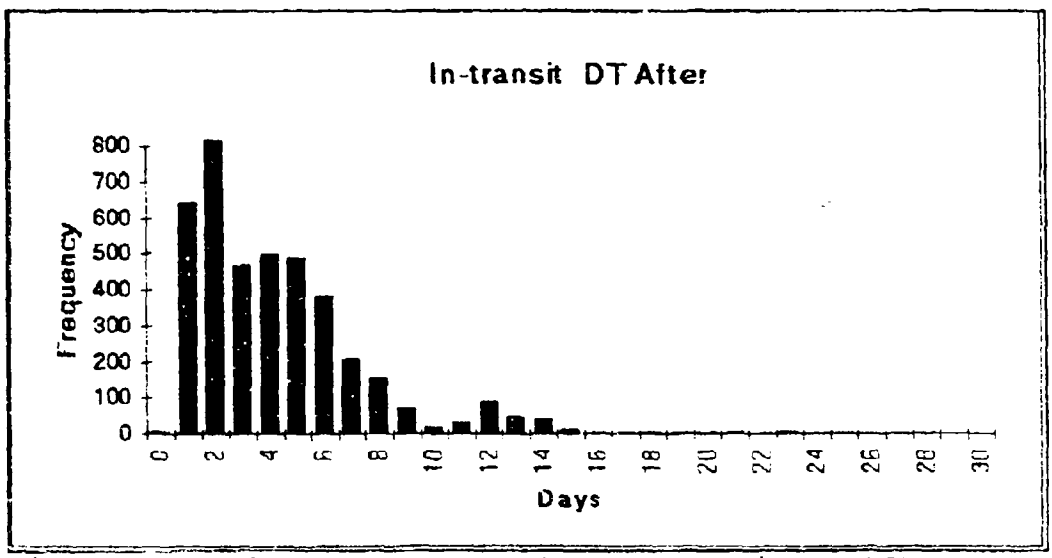

Figure 17. Histograph: Materiel In-Transit DT After

Appendix C. Descriptive Statistics

Listing Of Cell Sizes, Means And Variances

Total Processing Time

Hospital pair	Window	N	Mean	Variance
1	LTL before	741	13.162	23.65212
	LTL after	930	10.946	28.1435
	DT before	320	14.116	84.38588
	DT after	1568	8.122	10.8639
2	LTL before	413	14.701	34.43377
	LTL after	666	19.9	51.26942
	DT before	401	10.5	23.73061
	DT after	931	14.8	23.08262
3	LTL before	639	9.136	30.8952
	LTL after	346	8.546	12.31235
	DT before	485	11.006	49.74583
	DT after	305	10.27	22.25703
4	LTL before	717	8.257	25.78042
	LTL after	1050	8.856	19.21381
	DT before	605	9.428	34.81477
	DT after	713	10.501	35.42451
5	LTL before	203	7.433	16.65273
	LTL after	198	6.97	10.01938
	DT before	110	7.532	22.62164
	DT after	64	6.609	8.146577
6	LTL before	437	12.899	40.32011
	LTL after	440	13.548	28.90888
	DT before	235	12.017	34.20484
	DT after	419	9.387	11.50566

Listing Of Cell Sizes, Means And Variances For Depot Processing Time

Hospital pair	Window	N	Mean	Variance
1	LTL before	741	4.317	7.217
	LTL after	930	4.18	6.841
	DT before	320	6.978	19.845
	DT after	1568	5.474	9.185
2	LTL before	413	6.325	14.814
	LTL after	666	9.88	15.751
	DT before	401	7.866	12.22
	DT after	931	4.98	15.458
3	LTL before	639	5.477	26.087
	LTL after	346	6.607	14.123
	DT before	485	4.34	10.601
	DT after	305	6.55	16.222
4	LTL before	717	4.187	13.485
	LTL after	1050	4.621	9.786
	DT before	605	4.514	15.267
	DT after	713	5.029	13.172
5	LTL before	203	3.04	6.237
	LTL after	198	2.47	4.403
	DT before	110	3.45	12.305
	DT after	64	4.219	4.174
6	LTL before	437	6.025	25.772
	LTL after	440	5.605	21.433
	DT before	235	5.268	21.192
	DT after	419	5.895	5.75

Listing Of Cell Sizes, Means And Variances

Materiel Intransit Time

Hospital pair	Window	N	Mean	Variance
1	LTL before	741	8.845	12.726
	LTL after	930	6.767	14.076
	DT before	320	7.138	45.012
	DT after	1568	2.647	4.355
2	LTL before	413	8.376	15.393
	LTL after	666	9.31	25.901
	DT before	401	5.816	8.035
	DT after	931	6.934	8.063
3	LTL before	639	3.659	3.184
	LTL after	346	1.939	3.13
	DT before	485	6.666	26.925
	DT after	305	3.72	6.149
4	LTL before	717	4.07	6.076
	LTL after	1050	4.235	6.844
	DT before	605	4.914	10.195
	DT after	713	5.471	16.086
5	LTL before	203	4.394	5.814
	LTL after	198	4.5	3.236
	DT before	110	4.083	5.169
	DT after	64	2.391	3.099
6	LTL before	437	6.874	7.23
	LTL after	440	7.943	10.309
	DT before	235	6.749	11.95
	DT after	419	3.492	6.935

Appendix D. ANOVA Results

Full Model Unweighted ANOVA

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WINDOW	2	A B
METHOD	2	C T
HOS_PAIR	6	1 2 3 4 5 6

Number of observations in data set = 12932

Dependent Variable: TOTAL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	113876.210	4951.140	178.65	0.0001
Error	12908	357733.970	27.714		
Corrected Total		12931	471610.180		

R-Square	C.V.	Root MSE	TOTAL Mean
0.241463	47.89305	5.26442	10.9920

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	79.5647	79.5647	2.87	0.0902
METHOD	1	1170.0050	1170.0050	42.22	0.0001
WINDOW * METHOD	1	726.0550	726.0550	26.20	0.0001
HOS_PAIR	5	51042.4679	10208.4936	368.35	0.0001
WINDOW * HOS_PAIR	5	22235.3566	4447.0713	160.46	0.0001
METHOD*HOS_PAIR	5	13992.5116	2798.5023	100.98	0.0001
WINDOW*METHOD*HOS_PAIR	5	2242.2632	448.4526	16.18	0.0001

Full model Unweighted ANOVA

General Linear Models Procedure

Level of WINDOW	Level of METHOD	Level of HOS_PAIR	N	TOTAL Mean	TOTAL SD
A	C	1	930	10.9462366	5.30504480
A	C	2	666	19.1891892	7.16026653
A	C	3	346	8.5462428	3.50889558
A	C	4	1050	8.8561905	4.38335581
A	C	5	198	6.9696970	3.16534068
A	C	6	440	13.5477273	5.37669775
A	T	1	1568	8.1218112	3.29604335
A	T	2	931	14.8002148	4.80443791
A	T	3	304	10.2697368	4.71773621
A	T	4	713	10.5007013	5.95184912
A	T	5	64	6.6093750	2.85422098
A	T	6	419	9.3866348	3.39199915
B	C	1	741	13.1619433	4.86334425
B	C	2	412	14.7014563	5.86802941
B	C	3	639	9.1361502	5.55834752
B	C	4	717	8.2566248	5.07744231
B	C	5	203	7.4334975	4.08077612
B	C	6	437	12.8993135	6.34981214
B	T	1	319	14.1159875	9.18617851
B	T	2	401	10.4962594	4.87140749
B	T	3	485	11.0061856	7.05307234
B	T	4	605	9.4280992	5.90040440
B	T	5	109	7.5321101	4.75622167
B	T	6	235	12.0170213	5.84849017

Unweighted ANOVA Using Group

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB
HOS_PAIR	6	1 2 3 4 5 6

Number of observations in data set = 12932

Dependent Variable: TOTAL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	113876.210	4951.140	178.65	0.0001
Error	12908	357733.970	27.714		
Corrected Total	12931	471610.180			

R-Square	C.V.	Root MSE	TOTAL Mean
0.241463	47.89305	5.26442	10.9920

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	1863.0842	621.0281	22.41	0.0001
HOS_PAIR	5	51042.4679	10208.4936	368.35	0.0001
GROUP*HOS_PAIR	15	38746.1199	2583.0747	93.20	0.0001

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
TB - TA	0.1292	0.4907	0.8522	***
TB - CB	-0.5390	-0.1608	0.2174	
TB - CA	-1.2285	-0.8606	-0.4928	***
CB - TA	0.3292	0.6515	0.9737	***
CB - TB	-0.2174	0.1608	0.5390	
CB - CA	-1.0293	-0.6999	-0.3705	***

Unweighted ANOVA Using Group

General Linear Models Procedure

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

HOS_PAIR Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
1 - 2	-5.2288	-4.8329	-4.4371	***
1 - 3	0.2845	0.7206	1.1567	***
1 - 4	0.8690	1.2381	1.6072	***
1 - 5	2.5719	3.2468	3.9217	***
1 - 6	-2.0003	-1.5417	-1.0831	***
2 - 3	5.0841	5.5535	6.0229	***
2 - 4	5.6631	6.0710	6.4789	***
2 - 5	7.3829	8.0797	8.7766	***
2 - 6	2.8008	3.2912	3.7816	***
3 - 4	0.0705	0.5175	0.9646	***
3 - 5	1.8058	2.5263	3.2468	***
3 - 6	-2.7857	-2.2623	-1.7389	***
4 - 5	1.3267	2.0087	2.6908	***
4 - 6	-3.2489	-2.7798	-2.3108	***
5 - 6	-5.5229	-4.7885	-4.0542	***

Full Model Weighted ANCVA

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WINDOW	2	A B
METHOD	2	C T
HOS_PAIR	6	1 2 3 4 5 6

Number of observations in data set = 12932

Dependent Variable: TOTAL
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	4165.93479	181.12760	181.13	0.0001
Error	12908	12908.00018	1.00000		
Corrected Total	12931	17073.93497			

R-Square	C.V.	Root MSE	TOTAL Mean
0.243994	9.927974	1.00000	10.0725

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	3.31399	3.31399	3.31	0.0687
METHOD	1	48.73247	48.73247	48.73	0.0001
WINDOW * METHOD	1	30.24129	30.24129	30.24	0.0001
HOS_PAIR	5	1903.40533	380.68107	380.68	0.0001
WINDOW * HOS_PAIR	5	555.56152	111.11230	111.11	0.0001
METHOD*HOS_PAIR	5	459.69756	91.93951	91.94	0.0001
WINDOW*METHOD*HOS_PAIR	5	58.29176	11.65835	11.66	0.0001

Full Model Weighted ANOVA

General Linear Models Procedure

Level of BE_AFTER	Level of METHOD	Level of HOS_PAIR	N	Sum of Weights	TOTAL Mean	TOTAL SD
A	C	1	930	33.044930446	10.9462366	1.00000001
A	C	2	666	12.990199616	19.1891892	0.99999997
A	C	3	346	28.1018652	8.5462428	0.99999993
A	C	4	1050	54.648193149	8.8561905	0.99999995
A	C	5	198	19.761701822	6.9696970	1.00000008
A	C	6	440	15.220236827	13.5477273	0.99999998
A	T	1	1568	144.33122543	8.1218112	1.00000008
A	T	2	931	40.333376367	14.8002148	1.00000008
A	T	3	304	13.658605843	10.2697368	1.00000011
A	T	4	713	20.127307336	10.5007013	0.99999997
A	T	5	64	7.8560602815	6.6093750	1.00000002
A	T	6	419	36.416859181	9.3866348	0.99999992
B	C	1	741	31.32911553	13.1619433	0.99999994
B	C	2	412	11.964998314	14.7014563	0.99999999
B	C	3	639	20.682804433	9.1361502	0.99999995
B	C	4	717	27.811804462	8.2566248	1.00000001
B	C	5	203	12.19019344	7.4334975	1.00000011
B	C	6	437	10.838264082	12.8993135	1.00000005
B	T	1	319	3.7802532841	14.1159875	0.99999997
B	T	2	401	16.898006415	10.4962594	1.00000002
B	T	3	485	9.749560918	11.0061856	0.99999999
B	T	4	605	17.377681944	9.4280992	1.00000003
B	T	5	109	4.8183951296	7.5321101	1.00000010
B	T	6	235	6.8703727309	12.0170213	0.99999996

Weighted ANOVA Using Group

---------- Hospital Pair = 1 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 3558

Dependent Variable: TOTAL
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	842.235373	280.745124	280.75	0.0001
Error	3554	3554.000165	1.000000		
Corrected Total	3557	4396.235538			

R-Square	C.V.	Root MSE	TOTAL Mean
0.191581	10.62607	1.00000	9.41082

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	842.235373	280.745124	280.75	0.0001

Weighted ANOVA Using Group

---------- Hospital Pair = 1 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
			Weighted		
TB	- TA	5.83631	5.99418	6.15204	***
TB	- CB	0.78193	0.95404	1.12616	***
TB	- CA	3.00298	3.16975	3.33652	***
CB	- TA	4.92555	5.04013	5.15471	***
CB	- TB	-1.12616	-0.95404	-0.78193	***
CB	- CA	2.08914	2.21571	2.34227	***
			Unweighted		
TB	- TA	5.2108	5.9942	6.7775	***
TB	- CB	0.1000	0.9540	1.8081	***
TB	- CA	2.3422	3.1698	3.9973	***
CB	- TA	4.4716	5.0401	5.6087	***
CB	- TB	-1.8081	-0.9540	-0.1000	***
CB	- CA	1.5877	2.2157	2.8437	***

Weighted ANOVA Using Group

---------- Hospital Pair = 2 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 2410

Dependent Variable: TOTAL
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	559.893780	186.631260	186.63	0.0001
Error	2406	2406.000110	1.000000		
Corrected Total	2409	2965.893890			

R-Square	C.V.	Root MSE	TOTAL Mean
0.188777	6.851835	1.00000	14.5946

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	559.893780	186.631260	186.63	0.0001

Weighted ANOVA Using Group

---------- Hospital Pair = 2 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
			Weighted		
TB	- TA	-4.45752	-4.30396	-4.15040	***
TB	- CB	-4.38554	-4.20520	-4.02485	***
TB	- CA	-8.85543	-8.69293	-8.53043	***
CB	- TA	-0.25088	-0.09876	0.05336	
CB	- TB	4.02485	4.20520	4.38554	***
CB	- CA	-4.64887	-4.48773	-4.32660	***
			Unweighted		
TB	- TA	-5.1850	-4.3040	-3.422[illegible]	***
TB	- CB	-5.2399	-4.2052	-3.1705	***
TB	- CA	-9.6253	-8.6929	-7.7606	***
CB	- TA	-0.9716	-0.0988	0.7740	
CB	- TB	3.1705	4.2052	5.2399	***
CB	- CA	-5.4123	-4.4877	-3.5632	***

Weighted ANOVA Using Group

---------- Hospital Pair = 3 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 1774

Dependent Variable: TOTAL
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	57.3569829	19.1189943	19.12	0.0001
Error	1770	1769.9999512	1.0000000		
Corrected Total	1773	1827.3569341			

R-Square	C.V.	Root MSE	TOTAL Mean
0.031388	10.66833	1.00000	9.37354

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	57.3569829	19.1189943	19.12	0.0001

Weighted ANOVA Using Group

---------- Hospital Pair = 3 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	0.54834	0.73645	0.92456	***
TB - CB	1.71517	1.87004	2.02490	***
TB - CA	2.27899	2.45994	2.64090	***
CB - TA	-1.31275	-1.13359	-0.95442	***
CB - TB	-2.02490	-1.87004	-1.71517	***
CB - CA	0.41827	0.58991	0.76154	***
		Unweighted		
TB - TA	-0.3100	0.7364	1.7829	
TB - CB	1.0085	1.8700	2.7316	***
TB - CA	1.4532	2.4599	3.4666	***
CB - TA	-2.1303	-1.1336	-0.1369	***
CB - TB	-2.7316	-1.8700	-1.0085	***
CB - CA	-0.3649	0.5899	1.5448	

Weighted ANOVA Using Group

---------- Hospital Pair = 4 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 3085

Dependent Variable: TOTAL
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	64.3208197	21.4402732	21.44	0.0001
Error	3081	3080.9999057	1.0000000		
Corrected Total	3084	3145.3207254			

R-Square	C.V.	Root MSE	TOTAL Mean
0.020450	11.01813	1.00000	9.07595

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	64.3208197	21.4402732	21.44	0.0001

Weighted ANOVA Using Group

---------- Hospital Pair = 4 ----------

Tukey's Studentized Range (HSD) Test for variable: RANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
			Weighted		
TB	- TA	-1.21469	-1.07260	-0.93052	***
TB	- CB	1.02957	1.17147	1.31338	***
TB	- CA	0.44071	0.57191	0.70311	***
CB	- TA	-2.38002	-2.24408	-2.10813	***
CB	- TB	-1.31338	-1.17147	-1.02957	***
CB	- CA	-0.72409	-0.59957	-0.47504	***
			Unweighted		
TB	- TA	-1.8183	-1.0726	-0.3269	***
TB	- CB	0.4267	1.1715	1.9162	***
TB	- CA	-0.1167	0.5719	1.2605	
CB	- TA	-2.9576	-2.2441	-1.5306	***
CB	- TB	-1.9162	-1.1715	-0.4267	***
CB	- CA	-1.2531	-0.5996	0.0540	

Weighted ANOVA Using Group

---------- Hospital Pair = 5 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 574

Dependent Variable: TOTAL
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	4.48029291	1.49343097	1.49	0.2153
Error	570	570.00010238	1.00000018		
Corrected Total	573	574.48039529			

R-Square	C.V.	Root MSE	TOTAL Mean
0.007799	14.09705	1.00000	7.09368

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	4.48029291	1.49343097	1.49	0.2153

Weighted ANOVA Using Group

---------- Hospital Pair = 5 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	0.51697	0.92274	1.32850	***
TB - CB	-0.20735	0.09861	0.40457	
TB - CA	0.25510	0.56241	0.86972	***
CB - TA	0.45475	0.82412	1.19350	***
CB - TB	-0.40457	-0.09861	0.20735	
CB - CA	0.20644	0.46380	0.72116	***
		Unweighted		
TB - TA	-0.6251	0.9227	2.4705	
TB - CB	-1.0685	0.0986	1.2657	
TB - CA	-0.6093	0.5624	1.7347	
CB - TA	-0.5849	0.8241	2.2331	
CB - TB	-1.2657	-0.0986	1.0685	
CB - CA	-0.5179	0.4638	1.4455	

Weighted ANOVA Using Group

---------- Hospital Pair = 6 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 1531

Dependent Variable: TOTAL
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	238.956495	79.652165	79.65	0.0001
Error	1527	1526.999943	1.000000		
Corrected Total	1530	1765.956438			

R-Square	C.V.	Root MSE	TOTAL Mean
0.135313	9.001275	1.00000	11.1095

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	238.956495	79.652165	79.65	0.0001

Weighted ANOVA Using Group

-------------------------- Hospital Pair = 6 --------------------------------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	2.42078	2.63039	2.83999	***
TB - CB	-1.09034	-0.88229	-0.67425	***
TB - CA	-1.73850	-1.53071	-1.32291	***
CB - TA	3.33683	3.51268	3.68853	***
CB - TB	0.67425	0.88229	1.09034	***
CB - CA	-0.82211	-0.64841	-0.47472	***
		Unweighted		
TB - TA	1.5170	2.6304	3.7437	***
TB - CB	-1.9874	-0.8823	0.2228	
TB - CA	-2.634[illegible]	-1.5307	-0.4269	***
CB - TA	2.5786	3.5127	4.4467	***
CB - TB	-0.2228	0.8823	1.9874	
CB - CA	-1.5710	-0.6484	0.2742	

XX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Full Model Unweighted ANOVA

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WINDOW	2	A B
METHOD	2	C T
HOS_PAIR	6	1 2 3 4 5 6

Number of observations in data set = 12932

Dependent Variable: BANK

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	29749.8395	1293.4713	98.20	0.0001
Error	12908	170020.1905	13.1717		
Corrected Total	12931	199770.0300			

R-Square	C.V.	Root MSE	BANK Mean
0.148920	66.09103	3.62928	5.49134

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	1203.5058	1203.5058	91.37	0.0001
METHOD	1	44.7228	44.7228	3.40	0.0654
WINDOW * METHOD	1	30.5442	30.5442	2.32	0.1278
HOS_PAIR	5	11664.9449	2332.9890	177.12	0.0001
WINDOW * HOS_PAIR	5	5436.4372	1087.2874	82.55	0.0001
METHOD*HOS_PAIR	5	4357.3315	871.4663	66.16	0.0001
WINDOW*METHOD*HOS_PAIR	5	626.3994	125.2799	9.51	0.0001

Full model Unweighted ANOVA

Level of WINDOW	Level of METHOD	Level of HOS_PAIR	BANK N	BANK Mean	BANK SD
A	C	1	930	4.17956989	2.61547350
A	C	2	666	9.87987988	3.96874829
A	C	3	346	6.60693642	3.75809979
A	C	4	1050	4.62095238	3.12820117
A	C	5	198	2.46969697	2.09824459
A	C	6	440	5.60454545	4.62960438
A	T	1	1568	5.47448980	3.03068540
A	T	2	931	7.86573577	3.93170419
A	T	3	304	6.54934211	4.02765189
A	T	4	713	5.02945302	3.62930904
A	T	5	64	4.21875000	2.04294178
A	T	6	419	5.89498807	2.39785564
B	C	1	741	4.31713900	2.68642039
B	C	2	412	6.32524272	3.84885279
B	C	3	639	5.47730829	5.10753039
B	C	4	717	4.18688982	3.67213514
B	C	5	203	3.03940887	2.49721105
B	C	6	437	6.02517162	5.07664266
B	T	1	319	6.97805643	4.45482086
B	T	2	401	4.98004988	3.49565459
B	T	3	485	4.34020619	3.25591197
B	T	4	605	4.51404959	3.90727174
B	T	5	109	3.44954128	2.50789121
B	T	6	235	5.26808511	4.59659417

Full Model Weighted ANOVA

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WINDOW	2	A B
METHOD	2	C T
HOS_PAIR	6	1 2 3 4 5 6

Number of observations in data set = 12932

Dependent Variable: RANK
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	2482.54969	107.93694	107.95	0.0001
Error	12908	12906.89755	0.99991		
Corrected Total	12931	15389.44724			

R-Square	C.V.	Root MSE	RANK Mean
0.161315	19.37713	0.99996	5.16050

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	104.401033	104.401033	104.41	0.0001
METHOD	1	3.879586	3.879586	3.88	0.0489
WINDOW * METHOD	1	2.649627	2.649627	2.65	0.1036
HOS_PAIR	5	997.495114	199.499023	199.52	0.0001
WINDOW * HOS_PAIR	5	385.568349	77.113670	77.12	0.0001
METHOD*HOS_PAIR	5	315.248684	63.049737	63.06	0.0001
WINDOW*METHOD*HOS_PAIR	5	46.320035	9.264007	9.26	0.0001

Full Model Weighted ANOVA

General Linear Models Procedure

Level of BE_AFTER	Level of METHOD	Level of HOS_PAIR	N	Sum of Weights	RANK Mean	RANK SD
A	C	1	930	135.94503728	4.17956989	0.99997819
A	C	2	666	42.283029649	9.87987988	0.99999883
A	C	3	346	24.499044112	6.60693642	1.00001112
A	C	4	1050	107.29613734	4.62095238	0.99998174
A	C	5	198	44.969339087	2.46969697	0.99995802
A	C	6	440	20.529090655	5.60454545	1.00000552
A	T	1	1568	170.71311922	5.47448980	1.00000294
A	T	2	931	60.227713805	7.86573577	1.00000963
A	T	3	304	18.739982739	6.54934211	0.99999938
A	T	4	713	54.129972669	5.02945302	0.99999560
A	T	5	64	15.333013896	4.21875000	0.99995341
A	T	6	419	72.869565217	5.89498807	0.99997497
B	C	1	741	102.67424137	4.31713900	0.99998992
B	C	2	412	27.811529634	6.32524272	0.99998879
B	C	3	639	24.494959175	5.47730829	0.99999745
B	C	4	717	53.170189099	4.18688932	0.99998430
B	C	5	203	32.547699214	3.03940887	0.99992488
B	C	6	437	16.956386776	6.02517162	1.00000583
B	T	1	319	16.074577979	6.97805643	1.00001081
B	T	2	401	32.815057283	4.98004988	0.99998567
B	T	3	485	45.750400906	4.34020619	0.99999824
B	T	4	605	39.627955721	4.51404959	0.99999255
B	T	5	109	8.8581877286	3.44954128	1.00001222
B	T	6	235	11.089090223	5.26808511	0.99850487

Weighted ANOVA Using Group

---------- HOS_PAIR=1 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 3558

Dependent Variable: BANK
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	229.567219	76.522406	76.52	0.0001
Error	3554	3553.918153	0.999977		
Corrected Total	3557	3783.485372			

R-Square	C.V.	Root MSE	BANK Mean
0.060676	20.66877	0.99999	4.83816

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	229.567219	76.522406	76.52	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =1 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted			
TB	- TA	1.34568	1.50357	1.66146	***
TB	- CB	2.48878	2.66092	2.83306	***
TB	- CA	2.63169	2.79849	2.96528	***
CB	- TA	-1.27195	-1.15735	-1.04276	***
CB	- TB	-2.83306	-2.66092	-2.48878	***
CB	- CA	0.01099	0.13757	0.26415	***
		Unweighted			
TB	- TA	1.0269	1.5036	.9802	***
TB	- CB	2.1412	2.6609	.1806	***
TB	- CA	2.2950	2.7985	3.3020	***
CB	- TA	-1.5033	-1.1574	-0.8114	***
CB	- TB	-3.1806	-2.6609	-2.1412	***
CB	- CA	-0.2446	0.1376	0.5197	

Weighted ANOVA Using Group

---------- HOS_PAIR =2 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 2410

Dependent Variable: BANK
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	493.976030	164.658677	164.66	0.0001
Error	2406	2405.994079	0.999998		
Corrected Total	2409	2899.970109			

R-Square	C.V.	Root MSE	BANK Mean
0.170338	13.25433	1.00000	7.54470

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	493.976030	164.658677	164.66	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =2 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
			Weighted		
TB	- TA	-3.03925	-2.88569	-2.73213	***
TB	- CB	-1.52554	-1.34519	-1.16485	***
TB	- CA	-5.06233	-4.89983	-4.73733	***
CB	- TA	-1.69261	-1.54049	-1.38837	***
CB	- TB	1.16485	1.34519	1.52554	***
CB	- CA	-3.71577	-3.55464	-3.39350	***
			Unweighted		
TB	- TA	-3.4782	-2.8857	-2.2931	***
TB	- CB	-2.0411	-1.3452	-0.6493	***
TB	- CA	-5.5269	-4.8998	-4.2728	***
CB	- TA	-2.1275	-1.5405	-0.9535	***
CB	- TB	0.6493	1.3452	2.0411	***
CB	- CA	-4.1764	-3.5546	-2.9328	***

Weighted ANOVA Using Group

---------- HOS_PAIR =3 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 1774

Dependent Variable: BANK
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	111.794837	37.264946	37.26	0.0001
Error	1770	1770.002335	1.000001		
Corrected Total	1773	1881.797172			

R-Square	C.V.	Root MSE	BANK Mean
0.059409	18.38309	1.00000	5.43979

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	111.794837	37.264946	37.26	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =3 ----------

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	-2.39725	-2.20914	-2.02103	***
TB - CB	-1.29196	-1.13710	-0.98224	***
TB - CA	-2.44769	-2.26673	-2.08577	***
CB - TA	-1.25120	-1.07203	-0.89287	***
CB - TB	0.98224	1.13710	1.29196	***
CB - CA	-1.30127	-1.12963	-0.95799	***
		Unweighted		
TB - TA	-3.0035	-2.2091	-1.4148	***
TB - CB	-1.7910	-1.1371	-0.4832	***
TB - CA	-3.0309	-2.2667	-1.5026	***
CB - TA	-1.8286	-1.0720	-0.3155	***
CB - TB	0.4832	1.1371	1.7910	***
CB - CA	-1.8544	-1.1296	-0.4048	***

Weighted ANOVA Using Group

---------- HOS_PAIR =4 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 3085

Dependent Variable: BANK
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	19.3970047	6.4656682	6.47	0.0002
Error	3081	3080.9239324	0.9999753		
Corrected Total	3084	3100.3209371			

R-Square	C.V.	Root MSE	BANK Mean
0.006256	21.73657	0.99999	4.60048

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	19.3970047	6.4656682	6.47	0.0002

Weighted ANOVA Using Group

---------- HOS_PAIR =4 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	-0.65748	-0.51540	-0.37332	***
TB - CB	0.18526	0.32716	0.46906	***
TB - CA	-0.23810	-0.10690	0.02430	
CB - TA	-0.97851	-0.84256	-0.70662	***
CB - TB	-0.46906	-0.32716	-0.18526	***
CB - CA	-0.55859	-0.43406	-0.30953	***
		Unweighted		
TB - TA	-1.0178	-0.5154	-0.0130	***
TB - CB	-0.1746	0.3272	0.8289	
TB - CA	-0.5708	-0.1069	0.3570	
CB - TA	-1.3233	-0.8426	-0.3619	***
CB - TB	-0.8289	-0.3272	0.1746	
CB - CA	-0.8744	-0.4341	0.0063	

Weighted ANOVA Using Group

---------- HOS_PAIR =5 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 574

Dependent Variable: BANK
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	37.2618212	12.4206071	12.42	0.0001
Error	570	569.9498849	0.9999121		
Corrected Total	573	607.2117061			

R-Square	C.V.	Root MSE	BANK Mean
0.061365	33.32045	0.99996	3.00103

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	37.2618212	12.4206071	12.42	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =5 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	-1.17495	-0.76921	-0.36346	***
TB - CB	0.10418	0.41013	0.71608	***
TB - CA	0.67255	0.97984	1.28714	***
CB - TA	-1.54870	-1.17934	-0.80998	***
CB - TB	-0.71608	-0.41013	-0.10418	***
CB - CA	0.31236	0.56971	0.82706	***
		Unweighted		
TB - TA	-1.8056	-0.7692	0.2672	
TB - CB	-0.3714	0.4101	1.1916	
TB - CA	0.1949	0.9798	1.7648	***
CB - TA	-2.1228	-1.1793	-0.2358	***
CB - TB	-1.1916	-0.4101	0.3714	
CB - CA	-0.0877	0.5697	1.2271	

Weighted ANOVA Using Group

---------- HOS_PAIR =6 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 1531

Dependent Variable: BANK
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	5.43328925	1.81109642	1.81	0.1430
Error	1527	1526.2897786	0.99953489		
Corrected Total	1530	1531.7230678			

R-Square	C.V.	Root MSE	BANK Mean
0.003547	17.21711	0.99977	5.80683

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	5.43328925	1.81109642	1.81	0.1430

Weighted ANOVA Using Group

---------- HOS_PAIR =6 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
			Weighted		
TB	- TA	-0.83646	-0.62690	-0.41735	***
TB	- CB	-0.96508	-0.75709	-0.54909	***
TB	- CA	-0.54421	-0.33646	-0.12871	***
CB	- TA	-0.04562	0.13018	0.30599	
CB	- TB	0.54909	0.75709	0.96508	***
CB	- CA	0.24697	0.42063	0.59428	***
			Unweighted		
TB	- TA	-1.5243	-0.6269	0.2705	
TB	- CB	-1.6479	-0.7571	0.1337	
TB	- CA	-1.2262	-0.3365	0.5532	
CB	- TA	-0.6227	0.1302	0.8831	
CB	- TB	-0.1337	0.7571	1.6479	
CB	- CA	-0.3231	0.4206	1.1643	

Full model Unweighted ANOVA

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WINDOW	2	A B
METHOD	2	C T
HOS_PAIR	6	1 2 3 4 5 6

Number of observations in data set = 12932

Dependent Variable: SHIP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	56708.3524	2465.5805	225.75	0.0001
Error	12908	140980.6413	10.9220		
Corrected Total	12931	197688.9937			

R-Square	C.V.	Root MSE	SHIP Mean
0.286856	60.08037	3.30484	5.50070

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	1901.9619	1901.9619	174.14	0.0001
METHOD	1	1672.2247	1672.2247	153.11	0.0001
WINDOW * METHOD	1	1054.4363	1054.4363	96.54	0.0001
HOS_PAIR	5	18167.0099	3633.4020	332.67	0.0001
WINDOW * HOS_PAIR	5	7991.3169	1598.2634	146.33	0.0001
METHOD*HOS_PAIR	5	12101.6042	2420.3208	221.60	0.0001
WINDOW*METHOD*HOS_PAIR	5	1966.8785	393.3757	36.02	0.0001

Full model Unweighted ANOVA

General Linear Models Procedure

Level of WINDOW	Level of METHOD	Level of HOS_PAIR	N	SHIP Mean	SHIP SD
A	C	1	930	6.76666667	3.75176552
A	C	2	666	9.30930931	5.08931983
A	C	3	346	1.93930636	1.76907856
A	C	4	1050	4.23523810	2.61602020
A	C	5	198	4.50000000	1.79889983
A	C	6	440	7.94318182	3.21073780
A	T	1	1568	2.64732143	2.08681532
A	T	2	931	6.93447905	2.83962045
A	T	3	304	3.72039474	2.47977532
A	T	4	713	5.47124825	4.01081064
A	T	5	64	2.39062500	1.76038585
A	T	6	419	3.49164678	2.63338920
B	C	1	741	8.84480432	3.56733539
B	C	2	412	8.37621359	3.92344221
B	C	3	639	3.65884194	1.78448009
B	C	4	717	4.06973501	2.46498191
B	C	5	203	4.39408867	2.41126985
B	C	6	437	6.87414188	2.68877969
B	T	1	319	7.13793103	6.70912526
B	T	2	401	5.51620948	2.83467134
B	T	3	485	6.66597938	5.18896809
B	T	4	605	4.91404959	3.19289634
B	T	5	109	4.08256881	2.27355343
B	T	6	235	6.74893617	3.45680750

Full Model Weighted ANOVA

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WINDOW	2	A B
METHOD	2	C T
HOS_PAIR	6	1 2 3 4 5 6

Number of observations in data set = 12932

Dependent Variable: SHIP
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	6624.28884	288.01256	288.01	0.0001
Error	12908	12907.94710	1.00000		
Corrected Total	12931	19532.23594			

R-Square	C.V.	Root MSE	SHIP Mean
0.339146	22.06788	1.00000	4.53146

Source	DF	Type III SS	Mean Square	F Value	Pr > F
WINDOW	1	211.45944	211.45944	211.46	0.0001
METHOD	1	185.91734	185.91734	185.92	0.0001
WINDOW * METHOD	1	117.23185	117.23185	117.23	0.0001
HOS_PAIR	5	1659.81468	331.96294	331.96	0.0001
WINDOW * HOS_PAIR	5	493.32944	98.66589	98.67	0.0001
METHOD*HOS_PAIR	5	982.55168	196.51034	196.51	0.0001
WINDOW*METHOD*HOS_PAIR	5	175.16677	35.03335	35.03	0.0001

Full Model Weighted ANOVA

Level of BE_AFTER	Level of METHOD	Level of HOS_PAIR	N	Sum of Weights	SHIP Mean	SHIP SD
A	C	1	930	66.069906223	6.76666667	0.99999093
A	C	2	666	25.713292923	9.30930931	1.00000340
A	C	3	346	110.54313099	1.93930636	0.99994232
A	C	4	1050	153.41905319	4.23523810	0.99996798
A	C	5	198	61.186650185	4.59000000	1.00000627
A	C	6	440	42.681152391	7.94318182	0.99999211
A	T	1	1568	360.04592423	2.64732143	0.99997683
A	T	2	931	115.46570755	6.93447905	1.00002755
A	T	3	304	49.43893316	3.72039474	1.00002323
A	T	4	713	44.324257118	5.47124825	1.00001871
A	T	5	64	20.651823169	2.39062500	0.99999328
A	T	6	419	60.418168709	3.49164678	0.99998116
B	C	1	741	58.227251297	8.84480432	0.99999535
B	C	2	412	26.76541285	8.37621359	1.00001295
B	C	3	639	200.69995477	3.65884194	1.00005797
B	C	4	717	118.00526662	4.06973501	1.00001118
B	C	5	203	54.915720674	4.39408867	1.00001912
B	C	6	437	60.442600277	6.87414188	0.99996793
B	T	1	319	7.0869990225	7.13793103	1.00000402
B	T	2	401	49.90665837	5.51620948	1.00002250
B	T	3	485	18.012999071	6.66597938	1.00000724
B	T	4	605	59.342815105	4.91404959	0.99997975
B	T	5	109	21.087250919	4.08256881	1.00000437
B	T	6	235	19.685271967	6.74893617	0.99997984

Weighted ANOVA Using Group

---------- HOS_PAIR =1 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 3558

Dependent Variable: SHIP
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2601.01906	867.00635	867.03	0.0001
Error	3554	3553.90620	0.99997		
Corrected Total	3557	6154.92526			

R-Square	C.V.	Root MSE	SHIP Mean
0.422591	24.99833	0.99999	4.00021

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	2601.01906	867.00635	867.03	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =1 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	4.33274	4.49061	4.64848	***
TB - CB	-1.87899	-1.70687	-1.53476	***
TB - CA	0.20450	0.37126	0.53803	***
CB - TA	6.08291	6.19748	6.31206	***
CB - TB	1.53476	1.70687	1.87899	***
CB - CA	1.95157	2.07814	2.20470	***
		Unweighted		
TB - TA	3.9375	4.4906	5.0437	***
TB - CB	-2.3099	-1.7069	-1.1038	***
TB - CA	-0.2131	0.3713	0.9556	
CB - TA	5.7960	6.1975	6.5989	***
CB - TB	1.1038	1.7069	2.3099	***
CB - CA	1.6347	2.0781	2.5216	***

Weighted ANOVA Using Group

---------- HOS_PAIR =2 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 2410

Dependent Variable: SHIP
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	297.213038	99.071013	99.07	0.0001
Error	2406	2406.084426	1.000035		
Corrected Total	2409	2703.297464			

R-Square	C.V.	Root MSE	SHIP Mean
0.109945	14.15050	1.00002	7.06701

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	297.213038	99.071013	99.07	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =2 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
			Weighted		
TB	- TA	-1.57183	-1.41827	-1.26471	***
TB	- CB	-3.04035	-2.86000	-2.67966	***
TB	- CA	-3.95560	-3.79310	-3.63060	***
CB	- TA	1.28961	1.44173	1.59386	***
CB	- TB	2.67966	2.86000	3.04035	***
CB	- CA	-1.09424	-0.93310	-0.77196	***
			Unweighted		
TB	- TA	-1.9978	-1.4183	-0.8388	***
TB	- CB	-3.5406	-2.8600	-2.1794	***
TB	- CA	-4.4063	-3.7931	-3.1799	***
CB	- TA	0.8677	1.4417	2.0158	***
CB	- TB	2.1794	2.8600	3.5406	***
CB	- CA	-1.5412	-0.9331	-0.3250	***

Weighted ANOVA Using Group

---------- HOS_PAIR =3 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Dependent Variable: SHIP
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	443.309061	147.769687	147.77	0.0001
Error	1770	1770.055262	1.000031		
Corrected Total	1773	2213.364324			

R-Square	C.V.	Root MSE	SHIP Mean
0.200287	30.23054	1.00002	3.30797

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	443.309061	147.769687	147.77	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =3 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	2.75747	2.94558	3.13370	***
TB - CB	2.85227	3.00714	3.16200	***
TB - CA	4.54571	4.72667	4.90763	***
CB - TA	-0.24072	-0.06155	0.11761	
CB - TB	-3.16200	-3.00714	-2.85227	***
CB - CA	1.54790	1.71954	1.89118	***
		Unweighted		
TB - TA	2.3456	2.9456	3.5456	***
TB - CB	2.5132	3.0071	3.5011	***
TB - CA	4.1495	4.7267	5.3038	***
CB - TA	-0.6330	-0.0616	0.5099	
CB - TB	-3.5011	-3.0071	-2.5132	***
CB - CA	1.1721	1.7195	2.2670	***

Weighted ANOVA Using Group

---------- HOS_PAIR =4 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 3085

Dependent Variable: SHIP
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	83.0796030	27.6932010	27.69	0.0001
Error	3081	3080.9509997	0.9999841		
Corrected Total	3084	3164.0306027			

R-Square	C.V.	Root MSE	SHIP Mean
0.026258	22.53949	0.99999	4.43662

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	83.0796030	27.6932010	27.69	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =4 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
			Weighted		
TB	- TA	-0.69928	-0.55720	-0.41512	***
TB	- CB	0.70241	0.84431	0.98621	***
TB	- CA	0.54761	0.67881	0.81001	***
CB	- TA	-1.53746	-1.40151	-1.26557	***
CB	- TB	-0.98621	-0.84431	-0.70241	***
CB	- CA	-0.29003	-0.16550	-0.04097	***
			Unweighted		
TB	- TA	-0.9942	-0.5572	-0.1202	***
TB	- CB	0.4079	0.8443	1.2807	***
TB	- CA	0.2753	0.6788	1.0823	***
CB	- TA	-1.8196	-1.4015	-0.9834	***
CB	- TB	-1.2807	-0.8443	-0.4079	***
CB	- CA	-0.5485	-0.1655	0.2175	

Weighted ANOVA Using Group

---------- HOS_PAIR =5 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 574

Dependent Variable: SHIP
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	73.1537033	24.3845678	24.38	0.0001
Error	570	570.0102932	1.0000181		
Corrected Total	573	643.1639965			

R-Square	C.V.	Root MSE	SHIP Mean
0.113740	24.43051	1.00001	4.09328

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	73.1537033	24.3845678	24.38	0.0001

---------- HOS_PAIR =5 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	1.28618	1.69194	2.09771	***
TB - CB	-0.61748	-0.31152	-0.00555	***
TB - CA	-0.72474	-0.41743	-0.11012	***
CB - TA	1.63408	2.00346	2.37284	***
CB - TB	0.00555	0.31152	0.61748	***
CB - CA	-0.36328	-0.10591	0.15145	
		Unweighted		
TB - TA	0.8311	1.6919	2.5528	***
TB - CB	-0.9606	-0.3115	0.3376	
TB - CA	-1.0694	-0.4174	0.2345	
CB - TA	1.2198	2.0035	2.7871	***
CB - TB	-0.3376	0.3115	0.9606	
CB - CA	-0.6519	-0.1059	0.4401	

Weighted ANOVA Using Group

---------- HOS_PAIR =6 ----------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
GROUP	4	CA CB TA TB

Number of observations in by group = 1531

Dependent Variable: SHIP
Weight: WT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	598.513326	199.504442	199.51	0.0001
Error	1527	1526.939914	0.999961		
Corrected Total	1530	2125.453240			

R-Square	C.V.	Root MSE	SHIP Mean
0.281593	16.68227	0.99998	5.99427

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	3	598.513326	199.504442	199.51	0.0001

Weighted ANOVA Using Group

---------- HOS_PAIR =6 ----------

Tukey's Studentized Range (HSD) Test for variable: BANK
Alpha= 0.05 Confidence= 0.95 df= 3554 MSE= 9.116294
Critical Value of Studentized Range= 3.635
Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
		Weighted		
TB - TA	3.04769	3.25729	3.46689	***
TB - CB	-0.33325	-0.12521	0.08284	
TB - CA	-1.40204	-1.19425	-0.98645	***
CB - TA	3.20665	3.38250	3.55834	***
CB - TB	-0.08284	0.12521	0.33325	
CB - CA	-1.24273	-1.06904	-0.89535	***
		Unweighted		
TB - TA	2.6370	3.2573	3.8776	***
TB - CB	-0.7409	-0.1252	0.4905	
TB - CA	-1.8092	-1.1942	-0.5793	***
CB - TA	2.8621	3.3825	3.9029	***
CB - TB	-0.4905	0.1252	0.7409	
CB - CA	-1.5830	-1.0690	-0.5550	***

Appendix E. Bartlett Tests

Bartlett Test for Equal Variances

Result for Total Processing

MSE	27.7182194
LN MSE	3.32208994
C	1.001020548
B	1605.629887

Chi square TS (.95,23) = 35.17

Test: 1606 > 35.17 Reject H_o variances are not equal

Result for Depot Processing

MSE	13.1737485
LN MSE	2.5782261
C	1.001020548
B	1165.49464

Chi square TS (.95,23) = 35.17

Test: 1165 > 35.17 Reject Ho variances are not equal

Results for Material In-Transit

MSE	10.924124
LN MSE	2.39097355
C	1.001020548
B	2862.859515

Chi square TS (.95,23) = 35.17

Test: 2863 > 35.17 Reject Ho variances are not equal

Bartlett Test for Equal Variances by Cell

Total Processing Time						
Test Pair	Group	Variance	n-1 DF	(DF) Variance	LN Variance	LN (DF) Variance
1	LB	23.65212	740	17502.5688	3.163452752	2340.955036
	LA	28.1435	929	26145.3115	3.337316422	3100.366956
	DB	84.38588	319	26919.09572	4.435400089	1414.892628
	DA	10.8639	1567	17023.7313	2.385445366	3737.992389
2	LB	34.43377	412	14186.71324	3.539037769	1458.083561
	LA	51.26942	665	34094.1643	3.937094473	2618.167825
	DB	23.73061	400	9492.244	3.166765776	1266.70631
	DA	23.08262	930	21466.8366	3.139079953	2919.344357
3	LB	30.8952	638	19711.1376	3.430600832	2188.723331
	LA	12.31235	345	4247.76075	2.510602824	866.1579742
	DB	49.74583	484	24076.98172	3.906926641	1890.952494
	DA	22.25703	304	6766.13712	3.102657914	943.2080058
4	LB	25.78042	716	18458.78072	3.249615289	2326.724547
	LA	19.21381	1049	20155.28669	2.955629291	3100.455127
	DB	34.81477	604	21028.12108	3.550041722	2144.2252
	DA	35.42451	712	25222.25112	3.567403953	2539.991615
5	LB	16.65273	202	3363.85146	2.812574167	568.1399817
	LA	10.01938	197	1973.81786	2.304521217	453.9906798
	DB	22.62164	109	2465.75876	3.11890697	339.9608598
	DA	8.144577	63	513.234351	2.097597839	132.1486639
6	LB	40.32011	436	17579.56796	3.696850352	1611.826753
	LA	28.90888	439	12690.99832	3.364148814	1476.86133
	DB	34.20484	234	8003.93256	3.532367155	826.5739142
	DA	11.50566	418	4809.36588	2.442839088	1021.106739
		Totals	12912	357897.6494		41287.55678

Depot Processing Time						
Test Pair	Group	Variance	n-1 DF	(DF) Variance	LN Variance	LN (DF) Variance
1	LB	7.217	740	5340.58	1.976439354	1462.565122
	LA	6.841	929	6355.289	1.92293392	1786.405611
	DB	19.845	319	6330.555	2.987952086	953.1567155
	DA	9.185	1567	14392.895	2.217571719	3474.934883
2	LB	14.814	412	6103.368	2.69557268	1110.575944
	LA	15.751	665	10474.415	2.756903855	1833.341064
	DB	12.22	400	4888.000	2.503073954	1001.229581
	DA	15.458	930	14375.94	2.738126669	2546.457802
3	LB	26.087	638	16643.506	3.261437106	2080.796874
	LA	14.123	345	4872.435	2.647804674	913.4926126
	DB	10.601	484	5130.884	2.360948336	1142.698995
	DA	16.222	304	4931.488	2.786368346	847.0559771
4	LB	13.485	716	9655.26	2.601577957	1862.729817
	LA	9.786	1049	10265.514	2.280952793	2392.71948
	DB	15.267	604	9221.268	2.725693636	1646.318956
	DA	13.172	712	9378.464	2.578093365	1835.602476
5	LB	6.237	202	1259.874	1.830499298	369.7608581
	LA	4.403	197	867.391	1.482286127	292.010367
	DB	12.305	109	1341.245	2.510005684	273.5906195
	DA	4.174	63	262.962	1.428874809	90.01911295
6	LB	25.772	436	11236.592	3.249288631	1416.689843
	LA	21.433	439	9409.087	3.06493179	1345.505056
	DB	21.192	234	4958.928	3.053623752	714.547958
	DA	5.75	418	2403.5	1.749199855	731.1655393
		Totals	12912	170099.44		32123.37126

Materiel Intransit Time						
Test Pair	Group	Variance	n-1 DF	(DF) Variance	LN Variance	LN (DF) Variance
1	LB	12.726	740	9417.24	2.543647145	1882.298887
	LA	14.076	929	13076.604	2.644471219	2456.713763
	DB	45.012	319	14358.828	3.806929121	1214.41039
	DA	4.355	1567	6824.285	1.47132461	2305.565664
2	LB	15.393	412	6341.916	2.733912861	1126.372099
	LA	25.901	665	17224.165	3.254281578	2164.097249
	DB	8.035	400	3214	2.083806999	833.5227997
	DA	8.063	930	7498.59	2.087285696	1941.175697
3	LB	3.184	638	2031.392	1.158138268	738.892215
	LA	3.13	345	1079.85	1.141033005	393.6563866
	DB	26.925	484	13031.7	3.293055223	1593.838728
	DA	6.149	304	1869.296	1.816289467	552.151998
4	LB	6.076	716	4350.416	1.804346585	1291.912155
	LA	6.844	1049	7179.356	1.923372356	2017.617601
	DB	10.195	604	6157.78	2.321897404	1402.426032
	DA	16.086	712	11453.232	2.777949328	1977.899922
5	LB	5.814	202	1174.428	1.760268802	355.574298
	LA	3.236	197	637.492	1.174337999	231.3445858
	DB	5.169	109	563.421	1.642679246	179.0520378
	DA	3.099	63	195.237	1.131079479	71.25800716
6	LB	7.23	436	3152.28	1.978239036	862.5122198
	LA	10.309	439	4525.651	2.3330173	1024.194595
	DB	11.95	234	2796.3	2.480731278	580.4911191
	DA	6.935	418	2898.83	1.936581054	809.4908805
		Totals	12912	141052.289		28006.46933

Bibliography

Ammer, Dean S. Materials Management. Homewood IL: Richard D. Irwin, Inc., 1968.

-----. Purchasing and Materials Management for Healthcare Institutions. (Second Edition). Lexington MA: D.C. Heath & Co., 1983.

Ansari, A. and B. Modarress. Just-In-Time Purchasing. New York NY: The Free Press, 1990.

Arthur Andersen & Co., S.C., "Stockless Materials Management; How It Fits in the Healthcare Cost Puzzle," Health Industry Distributors Association (HIDA) Educational Foundation, Special Report (1990).

Bradley, Peter. "Delivering on Promises: World Class Means Reliability, Day After Day," Purchasing, 111: 79-81 (August 1991).

Byrne, Patrick M. and William J. Markham, "How the Flow of Materials Can Lead to Customer Satisfaction: A Study Points the Way," National Productivity Review, 11: 169-180 (Spring 1992).

Campbell, Donald T. and Julian C. Stanley. Experimental and Quasi-Experimental Designs for Research. Boston MA: Houghton Mifflin Company, 1966.

Celley, Albert F., William H. Clegg, Arthur W. Smith, and Mark A. Vonderembse, "Implementation of JIT in the United States," Journal of Purchasing and Materials Management, 22: 9-15 (Winter 1986).

Chapman, Stephen N. "Adapting Just-in-Time Inventory Controls to the Hospital Setting," Hospitals Materials Management, 11: 8-12 (October 1986).

Connelly, Timothy M. Chief of Transportation Section, Defense, Distribution Center - East, Mechanicsburg PA. Personal interview. 17 December 1992.

Defense Logistics Agency. The ABCs of DLA. Government Printing Office 307-576. Washington DC: Headquarters, Defense Logistics Agency, 1992.

-----. Dedicated Truck Conference Briefing. Defense Personnel Service Center, Philadelphia PA: December, 1992.

Defense Personnel Support Center. Philadelphia: Public Affairs Office, Defense Personnel Support Center, November 1992.

Department of Defense. Uniform Materiel Movement and Issues Priority System. DOD Directive 4410.6. Washington: Government Printing Office, October 1980.

Department of the Air Force. AF Medical Materiel Management System - General. AFM 67-1, Volume V. Washington: HQ USAF, May 1991.

Department of the Army. Medical Supply Operations. AR 40-61 Washington: Headquarters Department of the Army, 1 August 1989.

Department of the Army. Supply Policy Below the Wholesale Level. AR 710-2. Washington: Headquarters Department of the Army, 31 January 1992.

Department of the Army. Using Unit Supply System (Manual Procedures). DA PAM 710-2-1. Washington: Headquarters Department of the Army, 31 January 1992.

Department of the Army. Supply Support Activity Supply Systems: Manual Procedures. DA PAM 710-2-2. Washington: Headquarters Department of the Army, 31 January 1992.

Department of the Army. Requisitioning, Receipt and Issue System. DA PAM 725-50. Washington: Headquarters Department of the Army, 15 April 1988.

Freeland, James R. "A Survey of Just-in-Time Purchasing Practices in the United States," Production and Inventory Management Journal, 32: 43-49 (Second Quarter 1991).

Freund, Rudolf J. and Raymon C. Littell, SAS for Linear Models A Guide to the ANOVA and GLM Procedures. Cary NC: SAS Institute, Inc., 1985.

Gerchak, Yigal and Mahmut Parlar. "Investing in Reducing Lead-time Randomness in Continuous-Review Inventory Models," Engineering Costs & Production Economics, 21: 191-197 (May 1991).

Government Accounting Office. DOD Medical Inventory: Reductions Can Be Made Through the Use of Commercial Practices. Report Series GAO/NSLAD-92-58. Washington: GPO, December, 1991.

Gross, Donald and A. Soriano. "The Effect of Reducing Leadtime on Inventory Levels - Simulation Analysis," Management Science, 16-2: B-61 - B76 (October, 1969).

Harkenrider, Capt Thomas M. Stockless Medical Materials Management: Applications for the United States Air Force Medical Service. MS Thesis, AFIT/GLM/LSY/91S-27. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1991 (AD-A246 788).

Hoaglin, David C., Frederick Mosteller, and John W. Tukey. Fundamentals of Exploratory Analysis of Variance. New York NY: John Wiley & Sons, 1991.

Kirk, Roger E. Experimental Design: Procedures for the Behavioral Sciences (Second Edition). Monterey CA: Brooks/Cole Publishing, 1982.

"Koley's Medical Supply: Creating a Pure Stockless Program," Health Industry Today, 51: 42-55 (May 1988).

Lummus, Rhonda and Leslie Duclos-Wilson. "When JIT is not JIT," Production and Inventory Management Journal, 33: 61-65 (Second Quarter 1992).

Manoochehri, G. H. "Suppliers of the Just-In-Time Concept," Journal of Purchasing and Materials Management, 20: 16-21 (Winter 1984).

McHugh, Sandra H. An Analysis of the Defense Logistics Agency Medical Supplies Requisition Process. MS Thesis, AFIT/GLM/LSM/91S-47. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1991 (AD-A246 787).

Muller, E. J. "Selling the Process, Not Just the Product," Distribution, 90: 40-50 (January 1991).

Nataraajan, Rajan and Daniel R. Sersland. "The Just-in-Time Philosophy: Legacy of an Obsession," Review of Business, 1/2: 19-23 (Summer/Fall 1991).

Neter, John, William Wasserman, and Michael H. Kutner. Applied Linear Models: Regression, Analysis of Variance, and Experimental Design (Third Edition). Boston MA: Irwin Publishing, 1990.

-----. Applied Linear Models: Regression, Analysis of Variance, and Experimental Design (Second Edition). Homewood IL: Irwin Publishing, 1985.

Orlicky, Joseph. Materials Requirements Planning. New York NY: McGraw-Hill Book Company, 1975.

Pease, Alan. Chief of Logistics, Wright-Patterson Medical Center, Wright-Patterson Air Force Base OH. Personal interviews. November, 1992

Pettus, Michael R. "JIT/Stockless Programs for Hospitals," Federation of American Health Systems Review, 23: 71-73 (March/April 1990).

Reynolds, Daniel. Professor of Mathematics, Air Force Institute of Technology (AU), Wright-Patterson Air Force Base OH. Personal Interviews. July, 1993.

Romero, Bernardo P. "The Other Side of JIT in Supply Management," Production and Inventory Management Journal, 32: 1-2 (Fourth Quarter 1991).

SAS/STAT User's Guide, Version 6, Volume II (Second Edition). Cary NC: SAS Institute, 1990.

Schonberger, Richard J. Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity. New York: The Free Press, 1982.

Tesh, Steve. Chief of Research Studies, Logistics Control Agency, Ft Ord CA. Telephone interview. 16 November 1992.

U.S. Medicine, Inc. U.S. Medicine Directory of Major Federal Medical Treatment Facilities 1992-3. Washington: U.S. Medicine, Inc., 1992.

Vita

Captain Theresa O. Cantrell was born on 30 July 1956 in New York City, New York. She graduated from East Islip High School in 1974. She attended Michigan State University for two years before enlisting in the United States Army in 1977. She continued her education while assigned as a medical laboratory technician and was promoted to the rank of Staff Sergeant (E-6). In 1983, she received a Bachelor of Science in Business Management from the University of Maryland and was accepted to Officer Candidate School.

In December 1984 she accepted a commission in the United States Army as a Second Lieutenant in the Medical Service Corps. Her first assignment was to the 3d Infantry Division in Wuerzburg, Germany as the Division Medical Supply Officer. In 1986, she assumed command of HQ and Headquarters Company, 703d Support Battalion (Main).

Following several military schools, Captain Cantrell was assigned as the Medical Supply Accountable Officer at the 32d Medical Supply, Optical, and Maintenance Battalion, Fort Bragg, NC. During Operation Desert Shield/Storm she was Chief of Inventory Management for medical supply, 18th Airborne Corps and received the Bronze Star. In May 1992 she entered the School of Logistics and Acquisition Management, Air Force Institute of Technology.

Permanent address: 10387 Highway 78 East
Summerville , SC 29483

Major Walter E. Van Daele was born on 14 September 1952 in Antwerp, Belgium. In 1955 he emigrated to the U.S., and in 1961 became a naturalized citizen. In 1976 he graduated from The City College of New York with a BA in Biology and was designated as a Distinguished Military Graduate from the ROTC program at St. Johns University. He subsequently received a regular commission in the Army Medical Service Corps and began his military career as a platoon leader in the 702nd Medical Company, Ft. Meade Md.

After serving in various positions including Company Commander, Major Van Daele was reassigned as an military advisor to the reserves at Readiness Group Seneca, NY. His next assignment was as Chief, Services Division, Eisenhower Army Medical Center, Ft Gordon, Ga. where he served for 5 years. In 1988, he assumed the duties of Chief Inventory Management Division, U.S. Army Medical Materiel Center Europe (USAMMCE). There he was responsible for the inventory management of all depot level medical supplies in Europe. In 1990, he was assigned as Chief, Inventory Management for the 428th MEDSOM in Saudi Arabia providing medical supply support to the 7th Corps during Operation Desert Storm and was subsequently awarded the Bronze Star. On his return, he was reassigned as Chief, Readiness Division USAMMCE until his arrival at the Air Force Institute of Technology in May 1992.

Permanent address: 55-31 97th St.
Corona, NY 11368

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1993	Master's Thesis

4. TITLE AND SUBTITLE

AN INVESTIGATION OF THE DEFENSE LOGISTICS AGENCY'S DEDICATED TRUCK PROGRAM

5. FUNDING NUMBERS

6. AUTHOR(S)

Theresa O. Cantrell, Captain, USA
Walter E. Van Daele, Major, USA

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Institute of Technology,
Wright-Patterson AFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GIR/LAL/93D-2

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

OSD(HA)/HSO/MFIN-MED LOG
5205 Leesburg Pike Suite 1000
Falls Church, VA 22041
ATTN: LtCol Sietsma

DPSC
2800 S. 20th St.
Philadelphia, PA 19145
ATTN: DPSC-NA

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

In 1990, the Department of Defense purchased medical materiel from the Defense Logistics Agency totaling approximately $1 billion dollars. Congress has directed the Department of Defense to examine civilian healthcare practices to reduce these costs.

Just-in-Time inventory management is one of those practices. Research on Just-in-Time inventory for military facilities raised several concerns about its capability to support the military mission. However, there are many facets of Just-in-Time management that can be adopted without compromise of wartime capabilities.

This research identifies the results of the change in the Defense Logistics Agency's policy on delivery of medical materiel to Department of Defense medical facilities. The change was intended to decrease delivery time and increase reliability. It was hoped that in turn these changes would create savings and reduce inventory levels.

Statistical analysis of six pairs of hospitals, test and control, did not show any conclusive change in the delivery time although some individual hospitals did experience a decrease.

The increase in reliability was significant. Although, a few hospitals experienced a slight increase, most hospitals experienced a decrease in variance resulting in increased reliability and customer satisfaction.

14. SUBJECT TERMS

Reliability, Customer Service, Medical Supply, Hospital Supply, Just In Time Inventory, JIT

15. NUMBER OF PAGES

189

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL